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PROLACTIN, A PRODUCT OF THE ANTERIOR PITUITARY, AND THE PART IT PLAYS IN VITAL PROCESSES

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I

THE subject-matter of this paper includes more than the title suggests, and it may be of interest for any one of three reasons. *First:* the things recently learned about the several products of the anterior pituitary gland will help the present and all future generations of mankind to control some of the abnormality and disease that now attend the birth and life of man. *Second:* This new knowledge has bearing on a philosophical question—so, in the years ahead, it will creep into the mental outlook of the one living species that seeks to know itself. A few substances which are formed only in the pituitary gland are now surely known to be powerful agents for the coordination and control of some highly complicated life mechanisms—mechanisms which have long seemed too peculiar and complex for control by the nervous system. Once we see how the several pituitary substances act and interact these hitherto mysterious processes and mechanisms become simpler and comprehensible; and thus the new knowledge of these substances brings further evidence for a purely *naturalistic* basis of life at a high or human level. *Third:* To me it seems that just now, and for us all, there is both challenge and interest in the circumstance that though these pituitary substances serve so importantly in our lives their very existence has remained unknown and unsuspected until our own day. Our acquaintance with the services performed by this gland began after nearly all of my immediate readers were born, and the very beginning of our knowledge of the specific products of this gland falls almost within the last decade.

It seems well to pursue our brief consideration of the several products of the pituitary gland, and to acknowledge at once the incompleteness of our knowledge of them. We do not now know the precise number of different substances prepared and released into the blood by this gland; our information concerning the actions of each of these hormones is quite incomplete; and we have only fragmentary knowledge of the chemical nature of any one of these products. Yet, despite these great limitations, there is good reason to believe that a decade of investigation has provided the following items of important information: (*a*) Recognition of the several life processes which are most markedly affected by these products; (*b*) establishment of the fact that at least three or four distinct products are formed in and released by the anterior pituitary; (*c*) classification

of these products as of protein (or polypeptid) nature, and of a type known as hormones, and—most remarkable of all—hormones which commonly act upon other hormone-secreting glands; (*d*) finally, it is becoming clear that in large measure these hormones of the pituitary and the hormones of the glands which they call into action act largely as a self-regulating system—and that to one or another degree these pituitary hormones act upon the nervous system while the nervous system likewise shares in regulating the output of one or more of these hormones.

As a total result of this decade of study of the actions and interactions of these particular hormones in the bodies of higher animals a purely natural basis for some of the most mysterious performances and adjustments of our own bodies has become evident. Now, for the first time in the long history of man, human beings partly know a series of substances which largely control the rhythms of reproduction, the fuller expression of growth and some aspects of temperament and behavior. The brain and the anterior pituitary gland are now marked as the truly basic sources of the competence of man. It is not wholly without point to reflect that till now mankind has made its history—its conquests, its arts, its literature, its laws, its religions, its philosophies—while wholly ignorant of one of the two physical sources from which the abilities of an individual human being are derived.

The location, the structure and the closer associates of this master gland deserve notice. Quite like the older part of the brain the pituitary is not formed of separate right and left halves, but is a single or unpaired organ placed very close to the floor of the brain. The anterior pituitary gland is also pressed closely against another smaller organ called the posterior pituitary gland. This posterior gland prepares or secretes its own hormones—two of which are now fairly well known. Moreover, a very small amount of still another tissue lies between the two glands just mentioned and this tissue is usually known as the intermediate pituitary, while the hormone it produces is called "intermedin."

When one suitably prepares and magnifies some of the cells of the anterior pituitary gland three rather distinct kinds of cells can be found; their differences become much clearer after they have all been washed with certain solutions containing color or stain. In general, there is reason to think that those cells which remain uncolored after such a bath in colored fluid are resting cells—cells not actively producing any hormone—and also reason to believe that very small granules which assume a bluish color are granules associated with a hormone which is called "gonad-stimulating" hormone. Finally, there is reason to believe that other very small granules which assume a pink or eosin color are closely associated with the hormone "prolactin."

If the two kinds of colored granules just mentioned each contained only one hormone the task of investigating and of describing this subject would be greatly simplified. Unfortunately, however, when the blue granules are dissolved or extracted from the cells in which they lie we seem to obtain two or more somewhat different products, each having an action upon the sex glands but upon different parts of that gland. That particular product which acts upon the follicles of the ovary and the tubules of the testes is known as "follicle-stimulating" hormone (FSH), while another product which acts upon the hormone-secreting cells of ovary or testis is called "luteinizing" hormone (LH). Still worse for us all, our definite knowledge of these two products—if indeed they are two wholly distinct things—is complicated by several things only one of which will be considered here. It has been observed

that certain effects which can be produced by larger doses only of either follicle-stimulating or of luteinizing hormone, can also be produced by extremely minute amounts of a mixture of the two substances. In other words, when present together these two substances show the remarkable thing called "synergism" —or multiplication of effect—a property which will be met more than once in the present discussion.

It is likewise notable that the eosin-colored granules of which we have spoken probably do not represent prolactin alone. In addition, the product or extract obtained from these cells (actually the extracts are from all of the pituitary cells) perhaps includes "thyrotropin" which has special power to make thyroid glands grow and work, and another substance, "adrenotropin," which in like manner makes the adrenal gland (cortical part) grow and work. Here, too, among the members of this group of products, we again find those curious effects called synergisms. For example, in certain places and circumstances it has been observed that prolactin and thyrotropin have multiplied, rather than added, their separate capacities to produce heat, and also their separate abilities to produce bodily growth. It is also probable that prolactin and adrenotropin form a synergistic pair for increasing the store of glycogen and fat in the liver.

The writer has become so impressed with the number—and with the great functional importance—of synergized reactions among the pituitary hormones that, in the above statement and for the first time, he here ventures to use the observed fact of synergism between two pituitary products as evidence for their origin from the same type of pituitary cell. This venture is supported by several kinds of observations. We here note merely that it is well known that cells of the one type may display all evidence of very rapid hormone production at a time when cells of the other type give much or all evidence of complete inactivity. These useful synergisms of bodily activity would be present more continuously, and they would evidently be subject to a more automatic control, if the members of the synergizing pair were produced concurrently within the same type of pituitary cell.

II

Some of the actions of the several pituitary hormones, and of prolactin in particular, can be illustrated by means of photographs or other graphs. Such illustrations will considerably assist an understanding of a series of bodily changes which should now be examined more closely. Important clues to the general functions of the pituitary gland have been obtained by the surgical removal of the gland, and the first operations of this type were made in Europe more than three decades ago. In more recent years and in several laboratories it was found that when this operation—it is usually called hypophysectomy—is performed on real young animals the results are very striking.

The three dogs of Fig. 1 are all from the same litter. The two small ones had their pituitaries removed when 5 days old, and they grew but little thereafter till this photograph was taken 4 months later. On the same day the pituitary of the large dog was exposed and touched, but left in place. According to Dr. Kapran, of Kiev, Russia, who made that study and published this photograph a year ago, the dog subjected to this "sham" operation grew as well as did its litter mates which were not operated at all. The smaller rat of the pair shown here was deprived of its pituitary when 35 days old and when its weight was 70 gms. At the time this photograph was taken, 90 days later, its weight was only 75 grams, though its unoperated litter mate had meanwhile become the 200 gram rat

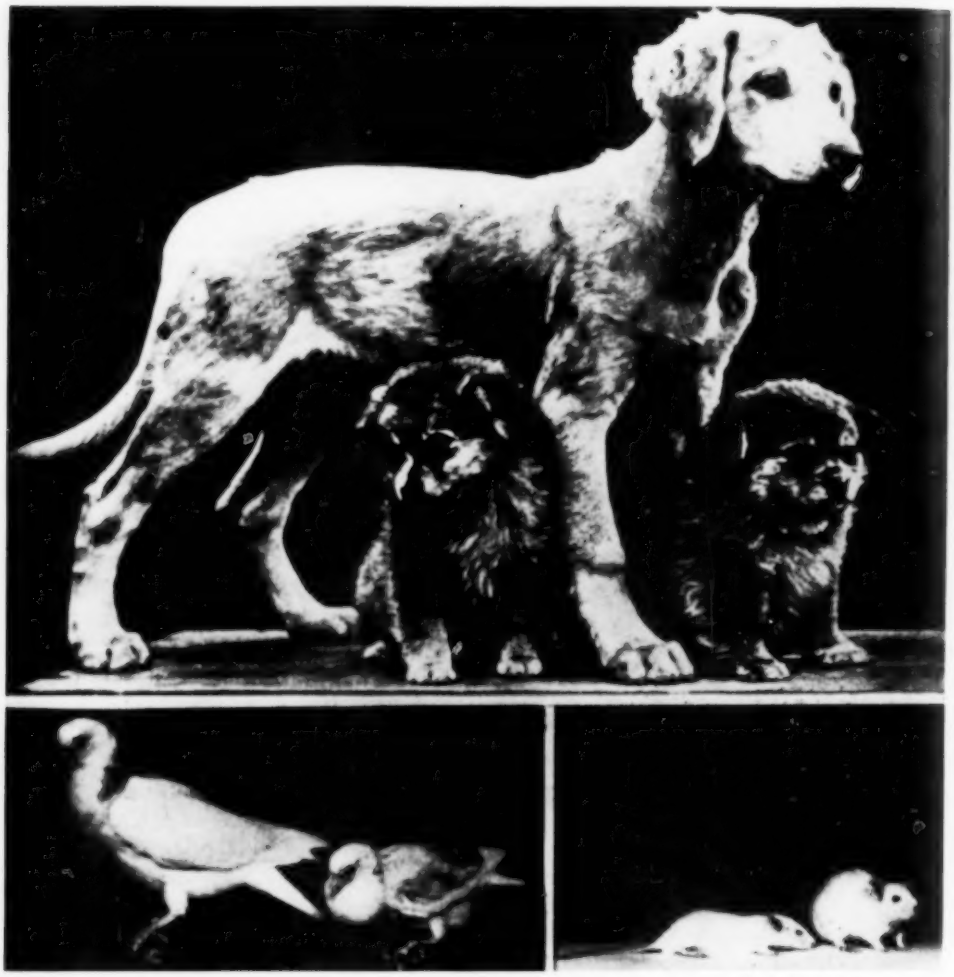

FIG. 1. EFFECTS OF PITUITARY REMOVAL ON BODY GROWTH IN ANIMALS
THE TWO SMALL PUPS WERE OPERATED WHEN 5 DAYS OLD AND GREW LITTLE THEREAFTER THOUGH THEIR LITTER MATE IS SHOWN TO HAVE MADE GOOD GROWTH WHEN ALL WERE PHOTOGRAPHED 4 MONTHS LATER (KAPRAN). THIS OPERATION LIKEWISE STOPS GROWTH IN YOUNG PIGEONS AND RATS.

of the photograph. The two pigeons shown are litter or clutch mates. The pituitary of the smaller one was removed 22 days before this photograph was taken, and though the feathers of this bird continued to grow its body weight remained practically unchanged. In the case of pigeons at least it has been shown that prolactin has a large share in causing the body to grow to normal size, and also to attain supernormal size. In animals generally it has hitherto been customary to ascribe the promotion of bodily growth to a special "growth" hormone.

It is unfortunate that you can not see on these same or other photographs the striking changes that occurred in certain internal organs of all these animals after they lost their pituitaries. Some of those vital internal organs suffered so much disorganization or atrophy that the really surprising thing is not that thereafter

their bodies ceased to grow, but rather that they were able to maintain their body weight following such injury to some of their vital organs. Preceding our own studies on this subject it had been shown in several laboratories that the thyroid gland, the sex glands, and the adrenals of rats, dogs and tadpoles are quickly and greatly damaged by the removal of their anterior pituitary glands. In pigeons we find that the liver and intestine also suffer more than does the body in general, and that prolactin—perhaps largely through its stimulation of appetite—especially restores these organs.

The first-found vital processes that could be assigned definitely to prolactin related to the formation of crop-milk in pigeons and to the stimulation of milk secretion in mammals. It was at this point in our knowledge of this hormone that it was given the name prolactin. When this hormone is injected into pigeons, even into very young ones, the sides of the crop-wall rapidly thicken and begin to secrete the so-called "milk" which all parent pigeons use in feeding and rearing their young. In Fig. 2 one notes the curious fact that not all of the crop-wall can be thickened and activated by prolactin—but only the two lateral pouches. In the other segments of Fig. 2 it can be seen that the mature, non-secreting mammary gland cells of the rabbit—such as are shown at the extreme left—can be made to secrete milk following the injection of prolactin; this is indicated by the enlarged, hazy, milk-filled bulbs of the central figure. And, the figure at the extreme right gives evidence that other pituitary hormones (FSH, thyrotropin, etc.) than prolactin will not stimulate those prepared cells to proceed with the secretion of milk. This capacity of prolactin to stimulate milk secretion has been observed in many mammals, including women. Other investigators have recently obtained evidence that the adrenal glands supply something that must accompany prolactin in order that milk secretion may occur and continue.

Later studies made with our several associates have shown that prolactin has still other actions which are, in many respects, of much greater consequence than the two restricted or local actions just described. A generalized or widespread action of prolactin is well illustrated by the effect of this hormone on the rate of heat production in pigeons. Thyrotropin was found to have no action on the heat production of pigeons whose thyroids had been removed; but in such pigeons (measured at 30° C.) prolactin definitely increased the rate of heat production. It was also learned that pigeons whose heat production was first much decreased as a result of the removal of their pituitaries show very great increases in their heat production (basal metabolism) after injections of prolactin. We do not yet know which organs of the body are thus stimulated by prolactin, but there is some reason to suspect that the intestine, liver and pancreas, and perhaps the adrenals, are especially involved.

Fig. 3 illustrates a part of the action just described. But it more especially deals with an additional aspect of this action of prolactin—an aspect which is of extraordinary interest. Here prolactin is observed to synergize, or augment, an effect on the basal metabolism which it shares with another pituitary hormone. It was first fully shown that the injection into doves of either thyrotropin alone or prolactin alone would increase their rate of heat production; also, that higher dosage of either of these hormones had greater effect than lower dosage. The curves of Fig. 3 show that a certain level of dosage of the two hormones given separately produced, in each case, a moderate increase in the metabolism of groups of doves injected for 2 and 6 days. When, however, only one half of the amount of hormone previously and separately used was given in combination, this

combination caused a much greater increase in the basal metabolism. Thus prolactin and thyrotropin have been observed to show a synergistic action on the basal metabolic rate of these animals.

In the light of what has just been noted concerning a synergism of prolactin and thyrotropin on heat production, and in view of the debated problem of the means by which the pituitary gland contributes so greatly to the processes of bodily growth, it is necessary to consider the action of these same hormones on growth in the dwarf mouse. By selecting from groups of these peculiar dwarfs only individuals proved incapable of further growth when left without treatment it was found that either prolactin or thyrotropin would induce some or much additional growth in these individuals. Of still greater interest was the observation that concurrent administration of minute amounts of the two hormones results in a marked synergism of the growth response in these animals. It has become clear that prolactin shares in the promotion of bodily growth in at least such animals as doves, pigeons and dwarf mice.

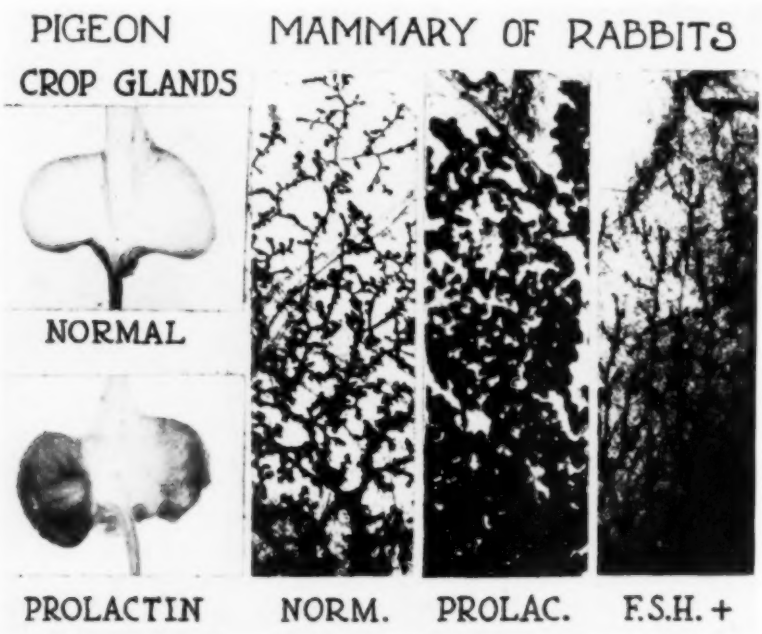

FIG. 2. SHOWING THE ACTION OF PROLACTIN ON CROP-SACS AND ON MAMMARY GLAND

WHEN UNSTIMULATED BY PROLACTIN THE WALLS OF THE PIGEON'S CROP ARE VERY THIN AND TRANSPARENT. BUT EITHER THE RELEASE OF PROLACTIN BY THE BIRD'S OWN PITUITARY OR INJECTION OF PROLACTIN FROM A HEN, A CALF OR A WHALE CAUSES THE LATERAL POUCHES OF THE CROP-WALL (AND THESE PARTS ONLY) TO THICKEN GREATLY AND PRODUCE "PIGEON MILK." AFTER THE CELLS AND DUCTS OF RABBIT MAMMARY GLANDS HAVE DEVELOPED PROPERLY 2–4 INJECTIONS OF PROLACTIN WILL CAUSE THEM TO FORM AND STORE MILK. OTHER PITUITARY HORMONES DO NOT STIMULATE MILK SECRETION.

At the moment it is not possible to state the extent to which prolactin affects the disposition of sugar and carbohydrate in the body; some investigators think that pure prolactin does not possess an action of this kind. For several years it has been known that some product or products of the anterior pituitary tends to

increase the amount of sugar in the blood of most animals; and everyone knows that under certain conditions the blood sugar of man increases greatly in amount, the kidneys excrete it, and a condition (still more involved) known as diabetes is established. There has been and there now is much discussion and investigation directed to a determination of the particular anterior pituitary hormone or hormones responsible for this blood sugar-raising and "diabetogenic" action.

The purposes of this communication require, despite uncertainties surrounding the subject, a brief statement of our own studies on this question. The abilities of the several available types of relatively purified hormones to increase the amount of sugar in the blood of fasting rabbits, rats, doves and pigeons has been examined. Of the various hormones used prolactin has most consistently increased the sugar content of the blood (glycemia) of these animals (except rats), though the increases are moderate in amount—usually only 10 to 40 per cent. In pigeons the typical glycemic action of prolactin is wholly absent during the first several hours, and under daily dosage it progressively increases for at least 5 days and this is accompanied by an increased deposit of glycogen and fat in the rapidly enlarging livers of these animals. The curves of Fig. 4 show that a single injection of highly purified prolactin causes in non-fasting rabbits a slow and fairly prolonged increase in the sugar of the blood. The fact that the increase does not reach its height within an hour or two, and does not quickly disappear, serves to exclude the possibility that this effect was produced by traces of posterior lobe hormones instead of by prolactin.

Adrenotropin, which can not now be prepared free from prolactin, has usually failed to give an indication of a similar and separate action on the blood sugar

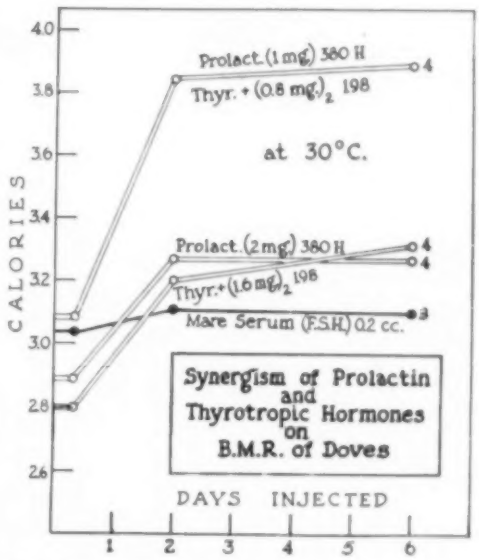

FIG. 3. PROLACTIN ALONE OR THYROTROPIN ALONE INJECTED DAILY FOR 2–6 DAYS INTO GROUPS (4 EACH) OF RING DOVES INCREASES THEIR RATE OF HEAT PRODUCTION. STILL SMALLER QUANTITIES OF THE TWO HORMONES INJECTED TOGETHER PRODUCES A MUCH GREATER INCREASE IN RATE OF HEAT PRODUCTION. SERUM FROM PREGNANT MARES—LACKING THESE TWO HORMONES BUT RICH IN FSH AND LH—HAS NO SIMILAR EFFECT.

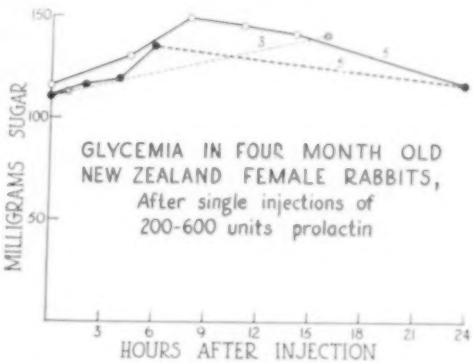

FIG. 4. A SINGLE INJECTION OF PROLACTIN INTO NON-FASTING RABBITS (GROUPS OF 3, 5, 5) CAUSES NO INCREASE IN THEIR BLOOD SUGAR DURING THE NEXT 3 HOURS. THEY DO SHOW MORE THAN NORMAL QUANTITIES OF SUGAR IN THEIR BLOOD AT 7–18 HOURS AFTER INJECTION.

of normal and hypophysectomized pigeons though it does seem to increase the ability of prolactin to form glycogen in

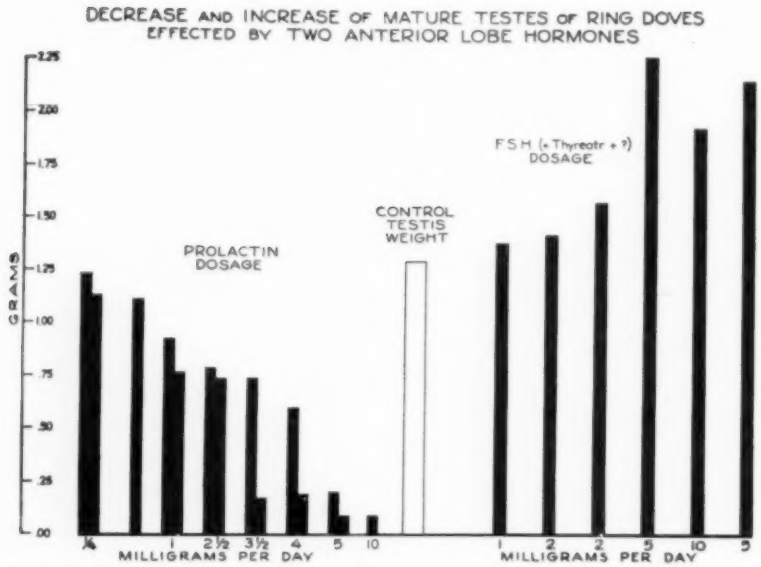

FIG. 5. THE TESTES OF MATURE BIRDS ATTAIN SUPERNORMAL WEIGHT AFTER TREATMENT FOR 7–10 DAYS WITH FSH. PROLACTIN HAS AN OPPOSITE EFFECT THROUGH ITS ABILITY TO PREVENT THE RELEASE OF FSH FROM THE PITUITARY OF THE BIRD THUS INJECTED. HEAVIER DOSAGE AND MORE POTENT HORMONE PREPARATIONS SHOWED THE GREATER EFFECTS ON TESTIS WEIGHT.

the liver. It seems clear that thyrotropin and gonad-stimulating hormones do not have glycemic and glycogen-storing effects similar to those of prolactin although a very few preparations which were rich in these hormones and quite free from prolactin have also shown marked power to increase the blood sugar of pigeons. These exceptional results nevertheless suggest that more than one pituitary product is directly or indirectly concerned in increasing the quantity of sugar in the blood. Whole or undivided extracts of anterior pituitary — and doubtless containing all the hormones of this gland—have usually elevated the blood sugar to a somewhat greater extent than does prolactin alone. It is therefore probable that more than one pituitary hormone shares in this ability to increase the blood sugar, and it is even possible that this increase is a synergized effect or response. Clearly, however, our purest preparations of prolactin have power to increase the blood sugar of rabbits, doves and pigeons. It is a singular fact that neither prolactin nor a mixture of all anterior pituitary hormones seems able to cause similar increases in the blood sugar of fasting normal rats.

We next consider an action of prolactin that has no definitely known parallel among other pituitary hormones. This marked peculiarity relates to the observed power of an excess of prolactin, when injected into the blood of an animal, to decrease—or in some cases wholly to eliminate—the output of follicle-stimulating hormone (FSH) by the pituitary cells of this animal. When prolactin thus shuts off an animal's current supply of FSH it of course becomes responsible —though indirectly—for a decreased activity and temporary atrophy of the reproductive system of this animal. In this performance we again meet an action of prolactin which is of widespread influence in the organism. Moreover, this action contributes directly to a broader theme of this address since we here seem

to find another part of an automatic mechanism, resident in the pituitary gland, through which periods of high ovarian and reproductive activity are appropriately alternated with phases of low activity.

In Fig. 5 the relative heights of the vertical bars at the right show that the sex glands of normal adult male birds can quickly become of supernormal size—normal size being indicated by the height of the central column—if for 7 to 10 days one daily adds some FSH to their blood. Indeed it is found that the more of this hormone that is added the greater is the excess of weight attained by their testes. On the other hand, when prolactin is added to the blood of such birds their testes quickly diminish in size; and indeed under very high dosage of prolactin it is found that the testes of these birds diminish in size almost to the point of disappearance. Precisely similar effects on the ovaries of pigeons and fowl invariably occur after the injection of these two hormones. We here omit a discussion of the somewhat involved experiments which prove that this action of prolactin is accomplished through its ability to stop the production of gonad-stimulating hormone in the animal's own pituitary.

A response apparently similar to that just described has been observed in female rats. Fig. 6 shows the effect of injections of prolactin on the heat or rut cycles of mature female rats. The ovaries of such rats usually reach a high point in their activity at intervals of about 5 days. High and low points in this ovarian activity are here expressed in the form of short curves. The high points of ovarian activity are otherwise known to reflect either high points in the output, or in an accumulated output, of FSH from the pituitaries of these rats. To several female rats showing these regular ovarian cycles prolactin was

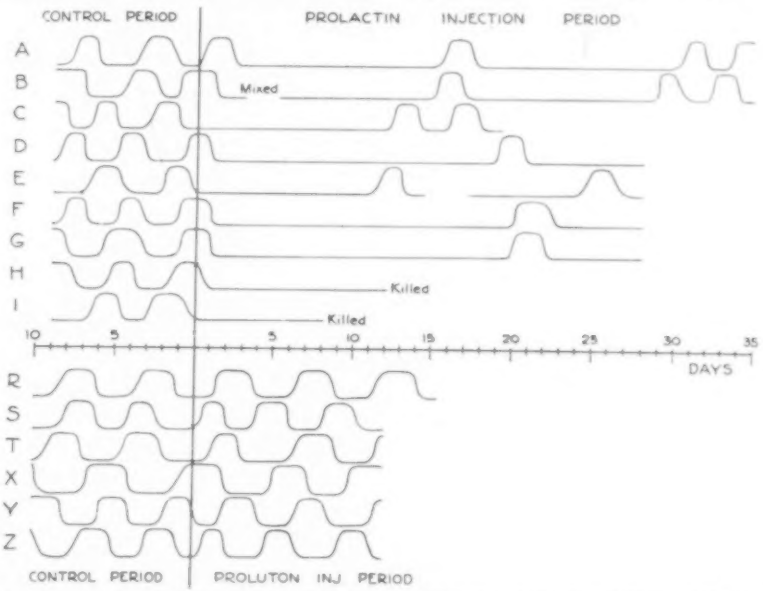

FIG. 6. THE ACTION OF PROLACTIN ON THE HEAT CYCLES OF RATS

THE NORMAL HEAT CYCLES OF 9 MATURE FEMALE RATS (A–I) WERE QUICKLY, THOUGH NOT PERMANENTLY, INTERRUPTED BY DAILY INJECTIONS OF 30 UNITS OF PROLACTIN. THE VERTICAL LINE INDICATES THE POINT AT WHICH PROLACTIN TREATMENT WAS STARTED. THE CYCLES OF 6 RATS (R–Z) GIVEN MODERATE OR LOW DOSAGE OF PROLUTON (PROGESTERONE) WERE NOT INTERRUPTED.

given daily, beginning at the point where the black vertical line crosses the record for each rat. Immediately after beginning treatment with prolactin it is notable that two or more of the next succeeding points of high ovarian activity were absent. At the constant level of prolactin dosage used in our tests ovarian activity was occasionally resumed; but other investigators who have used mice in similar tests have shown that by raising the level

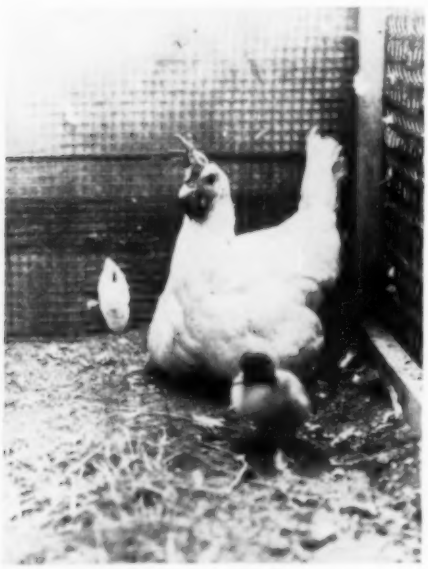

FIG. 7. THE INITIATION OF BROODINESS IN FOWL

MOST WHITE LEGHORN HENS LACK A GENETIC FACTOR FOR "BROODINESS" AND CAN NOT BE MADE WHOLLY BROODY BY PROLACTIN. THIS EXCEPTIONAL LEGHORN HEN WAS MADE BROODY BY 5 DAILY INJECTIONS OF PROLACTIN; THEREAFTER SHE INCUBATED EGGS AND ACCEPTED FULL CARE AND DEFENSE OF 2 DUCKLINGS.

of prolactin dosage these occasional resumptions of ovarian activity can also be suppressed. It should now be emphasized that others have supplied evidence that the luteinizing hormone (LH), rather than prolactin, is responsible for the suppression of these ovarian cycles in rats and mice. Again, we have found that prolactin does not produce atrophy of the testes in male rats. Though these conditions in mammals require further study it seems clear and certain that in birds of both sexes prolactin, not LH, is responsible for the large amount of anti-gonad action observed by us.

Still a third consequence of this ability of prolactin to shut off the supply of FSH can be observed in a rapid decrease of blood calcium in actively reproducing female birds (and practically in this type of animal only). Though this complete story can not be told here its outlines can be quickly stated. In periods of egg production the blood of a bird has double the usual amounts of calcium; and this extra calcium results from the circumstance that the gonad-stimulating hormone which stimulates her ovary to produce eggs likewise induces her ovary to produce extraordinary amounts of the sex hormone "estrin." This estrin acts upon her parathyroid glands and these glands in turn produce more of their hormone—a hormone which mobilizes calcium from her bones or from other sources. But prolactin can stop this whole cycle of events at its source through its ability to check the release of FSH from the bird's own pituitary gland.

We may therefore conclude our examination of three different consequences of an anti-gonad action of prolactin (its ability to restrict output of FSH) with the observation that, under certain restricted conditions, this hormone has been found capable of lowering the calcium of the blood; and, the amount or level of the blood calcium is already known to have significance in several vital processes though its full importance is probably not yet known.

At this point we should consider the rôle of prolactin in the phenomena of broodiness and maternal behavior in animals. These phenomena are of course psychical rather than physical—they involve responses of the brain. It is probable that the ability of prolactin to

induce broodiness and maternal behavior is in part related to the already described anti-gonad action of this hormone; this probability is better supported by the evidence from birds than by that obtained from mammals. Though the precise way in which prolactin thus assists in building an element of consciousness is essentially unknown, it seems to have been established as a fact that this pituitary hormone cooperates with nervous or brain tissue in the building of a mental state. Incidentally, this relationship between a hormone and an element of consciousness is anticipated in the modern view of the nature of the mind. Nowadays, mind is not seen as a thing apart—it is "body-brain" that builds and conserves the phenomena of mind.

The hen which in Fig. 7 seems so full of responsibilities was care-free and steadily laying eggs when she received the first of a series of 5 daily injections of prolactin. By the end of the third day she ceased laying eggs and was clucking. By the fourth day she was broody and sat upon eggs. Thereafter, when two young ducks were offered she accepted them and thereafter fiercely defended them against all human intrusion. Similar results were obtained with other genetically suitable fowl if injections were begun while the birds were actively laying eggs. Otherwise only the clucking response was obtained. Pituitary hormones other than prolactin showed no capacity to induce broodiness in fowl. Moderate or low dosage with a series of other hormones—including the corpus luteum hormone, progesterone—was also ineffective in laying fowl. But in ring doves it has been found that progesterone

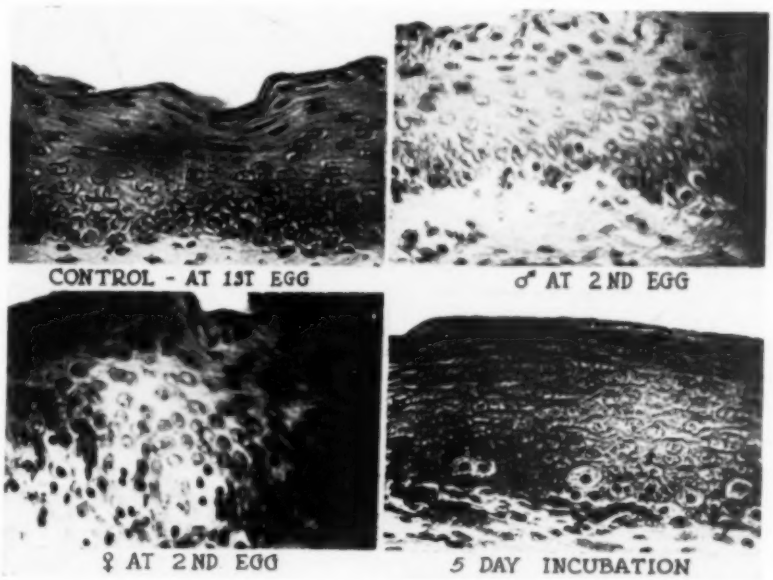

FIG. 8. MITOSES IN THE CROP-WALL OF PIGEONS IN RELATION TO BROODINESS

DIVIDING CELLS ARE LARGE CLEAR CELLS WITH LARGE VERY BLACK NUCLEI—ALL HELD BY COLCHICINE IN A MID-STAGE OF DIVISION. BEFORE BROODINESS BEGINS IN PIGEONS (CONTROL—AT 1ST EGG) FEW OR NO DIVIDING CELLS ARE PRESENT AND THIS SHOWS THAT DETECTABLE AMOUNTS OF PROLACTIN ARE NOT THEN PRESENT IN THE BIRD'S BLOOD. BUT 48 HOURS LATER (♂ AND ♀ AT 2ND EGG) THE BIRDS WERE BROODY AND THEIR CROP-SACS CONTAINED MANY DIVIDING CELLS. IT IS THUS FOUND THAT THE BEGINNING OF BROODY BEHAVIOR IN PIGEONS COINCIDES CLOSELY WITH AN INCREASED RELEASE OF PROLACTIN FROM THE PITUITARY GLAND.

ACTION OF PROLACTIN AND OF COMBINED A.P. HORMONES ON SIZE OF LIVER AND PANCREAS
(Groups of 7-10 hypophysectomized pigeons injected for 10 days)

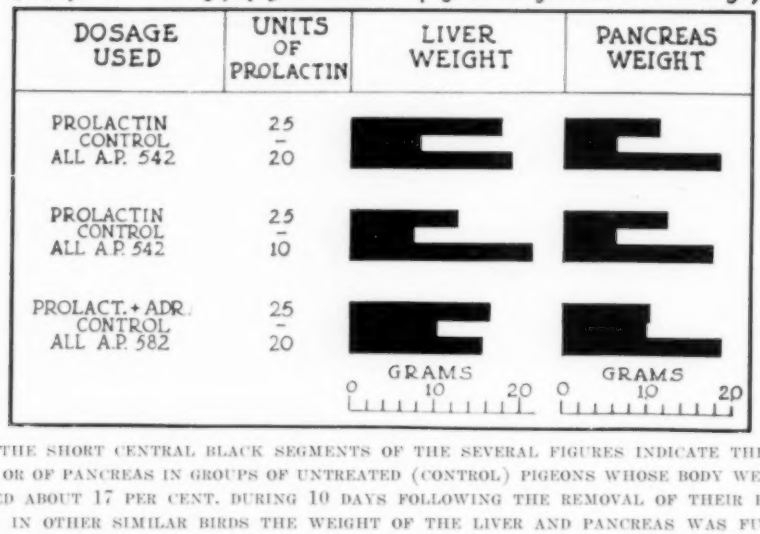

FIG. 9. THE SHORT CENTRAL BLACK SEGMENTS OF THE SEVERAL FIGURES INDICATE THE WEIGHT OF LIVER OR OF PANCREAS IN GROUPS OF UNTREATED (CONTROL) PIGEONS WHOSE BODY WEIGHT HAD DECREASED ABOUT 17 PER CENT. DURING 10 DAYS FOLLOWING THE REMOVAL OF THEIR PITUITARY GLANDS. IN OTHER SIMILAR BIRDS THE WEIGHT OF THE LIVER AND PANCREAS WAS FULLY SUSTAINED BY INJECTIONS OF PROLACTIN DURING THIS 10-DAY PERIOD. WHEN SUCH BIRDS WERE TREATED WITH ALL ANTERIOR PITUITARY (A.P.) HORMONES, INCLUDING PROLACTIN, THE LIVER AND PANCREAS MADE ACTUAL GAINS IN WEIGHT DESPITE THE LOSS OF THEIR PITUITARIES.

can initiate broody behavior in females with active ovaries, also in mature males, though probably not in very young males.

From another angle this same question was studied in the pigeon. It is well known that the behavior of pigeons changes markedly at or immediately after the time their eggs are laid. They may have been quite wild before, but now the brooding bird permits human approach and the handling of eggs beneath its breast. Since the crop-sacs of a pigeon provide the best and surest test for any slight increase in the amount of prolactin circulating in its blood it was highly important to learn whether the onset of incubation in these birds is or is not accompanied by the release of prolactin as this would be shown by a resulting increase of cell divisions in their crop-sacs.

The main result of this inquiry can be observed in Fig. 8. It had first been learned that when we ourselves inject prolactin into a bird an increase in the rate of cell division in the crop wall can be observed as early as 20 to 30 minutes later. Dividing cells of the crop-wall are large cells each with a large central black body—the nucleus. Using the drug colchicine to make each cell division more evident, one finds (in the upper left segment of the figure) few or no cell divisions in the crop-sacs of birds examined on the day on which the first of their two eggs was laid; at that time few cell divisions occur and the birds are not yet broody. The two photographs at upper right and lower left are from crop-sacs taken 48 hours later—and only a few hours after these birds had begun to incubate their eggs. In these cases one finds definitely larger numbers of cell divisions, and this shows that more prolactin was then being produced than in the non-broody period just preceding egg-laying. The photo at the lower right shows conditions in tissues taken after a further period of 5 days—with cells con-

tinuing to divide while broodiness also continues. This crucial evidence therefore indicates that the normal, wholly natural broodiness of pigeons is accompanied by an increased production of the hormone prolactin. And this result rather dramatically strengthens the basis for the conclusion that prolactin normally plays an essential part in the development of the broody instinct in birds.

The action of prolactin and of many other hormones on the maternal behavior of young rats has been studied in a series of more than 1500 tests. Those studies make it clear that certain hormones, particularly FSH and estrin (and prolan) may actually reduce or prevent the exhibition of maternal behavior in these young rats. However, it is found that besides prolactin certain other hormones —notably progesterone, the male hormone (testosterone), and intermedin, and even carbolic acid—also tend to call out this behavior in rats. In the main, it is found that both normal males and females, and castrate males and females, tend to respond or to fail to respond to a particular hormone in about the same way. Again, on a percentage basis prolactin heads the list of hormones and substances capable of developing the maternal or parental instinct, and it is possible that those other substances which exert positive effects do so in part by causing the release of prolactin from the rat's own pituitary. This and still other challenging questions connected with this subject can not be satisfactorily answered

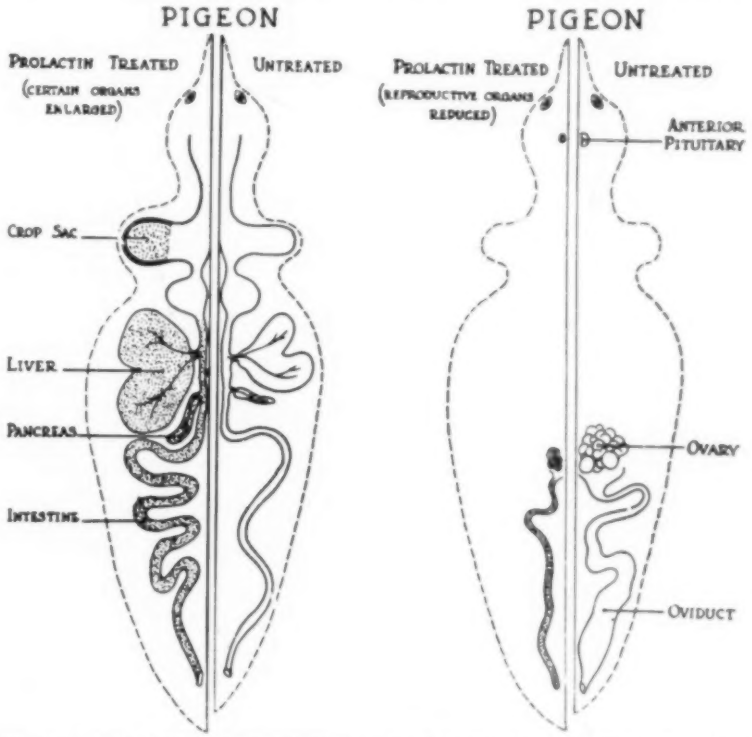

FIG. 10. THE GROSS STRUCTURAL CHANGES INDUCED IN PIGEONS BY PROLACTIN

PROLACTIN INCREASES THE WEIGHT OR SIZE OF THE BODY AS A WHOLE AND IT TENDS TO INDUCE GROWTH IN SEVERAL PARTS OF THE DIGESTIVE APPARATUS—CROP-SACS, LIVER, INTESTINE, PANCREAS. IT DECREASES THE OUTPUT OF FOLLICLE-STIMULATING HORMONE FROM THE PITUITARY GLAND AND IN THIS INDIRECT WAY IT CAUSES A PRONOUNCED ATROPHY OF THE TESTIS, OVARY AND OVIDUCT.

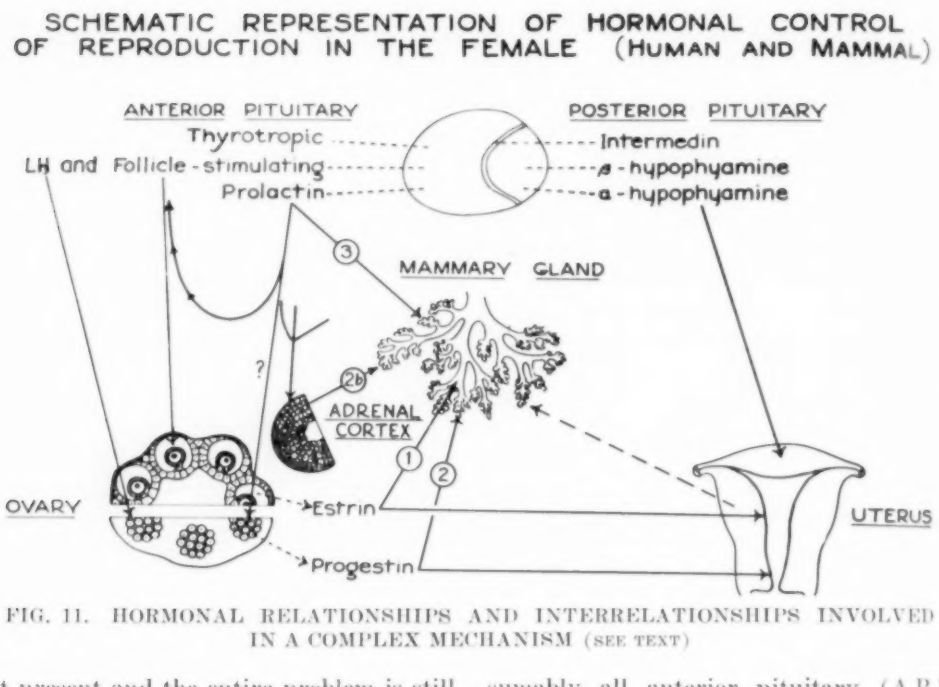

FIG. 11. HORMONAL RELATIONSHIPS AND INTERRELATIONSHIPS INVOLVED IN A COMPLEX MECHANISM (SEE TEXT)

at present and the entire problem is still under active study.

The story of what prolactin does in the animal body will perhaps long remain incomplete; but at present a very significant part of that story seems to be suggested by the now known fact that in pigeons prolactin promotes bodily growth and growth in some important organs—organs mainly associated with the digestive system. Fig. 9 shows—by the length of the ribbons of black—that in birds deprived of their pituitaries prolactin specifically promotes rapid growth in the liver during a 10-day period; and, perhaps indirectly—through increased appetite and food intake after pituitary removal—it also sustains or over-sustains the (intestine and) pancreas. The graph indicates too that prolactin admixed with adrenotropin (ADR.) has probably no greater power to enlarge the liver and sustain the intestine and pancreas than has prolactin alone. In each of the tripartite blocks the lower ribbon represents the amount of growth obtained when presumably all anterior pituitary (A.P.) hormones, including prolactin, were injected together. The results obtained with this mixture suggest that something in addition to prolactin was present and assisted growth, particularly that of the pancreas.

While considering this rapid growth of the liver in pigeons as a result of potent prolactin treatment—its weight may be doubled in 5 days—it should be noted that this growth is accompanied by the deposit of many granules of fat in the liver cells. Moreover, it seems that when adrenotropin is added to the prolactin this deposit of fat in the liver is notably increased. On the other hand, a mixture of thyrotropin and FSH usually seems to have no ability to cause fat to accumulate in liver cells. Practically all that has just been said concerning the hormonal control of the deposit of fat in these liver cells would also apply to the deposit of the carbohydrate, glycogen, in these same cells.

The removal of the pituitary glands

of a large number of pigeons has been found to result in a great loss of appetite and in a marked diminution in the length and empty weight of the bird's intestine. If, however, one begins the injection of prolactin into these birds immediately following pituitary removal their loss of appetite and the atrophy of their intestines are wholly prevented. Indeed, appetite is increased beyond normal, the intestines increase in weight and length, and the bird itself grows instead of losing much weight. Thyrotropin and FSH have no comparable or similar effect upon appetite, intestine, or body growth. Undivided pituitary extracts, containing prolactin and all other pituitary hormones, usually seem to support those several structures and processes somewhat better than does the purified prolactin alone.

The diagrams of Fig. 10 supply a picture of some of the structural changes effected in the bodies of pigeons by a few injections of prolactin. In the pair of half-figures at the left the organs which are either stimulated to growth or have their size markedly sustained by prolactin are indicated by stippling. These several organs are essentially parts of the alimentary system and include the crop-sacs, the intestine, the liver and the pancreas. The size or weight of the body as a whole is increased. In the pigeon, though not in the rat, prolactin is thus seen to be doing just about those things which a "growth" hormone might be expected to do.

The two half-figures at the right depict changes in the reproductive system of the prolactin-injected bird after this hormone cuts off the current supply of FSH from the bird's own pituitary. If it were possible to do so the pituitary of this treated half should be represented as having been affected. The greatly diminished size of the ovary and oviduct of the injected half are shown without exaggerating the degree of their divergence from their former normal state.

Several significant segments of our present knowledge of the hormonal control of reproduction are put together in Fig. 11. The relationships expressed on this diagram have been learned in many laboratories in different parts of the world. This graph first of all reflects the fact that the central control of this complicated system resides in the anterior pituitary, and that the gonad-stimulating hormone (or hormones) is here of primary importance. That hormone carries responsibility for stimulation of both growth and activity in the ovary and testis. As a prime result of such stimulation the ovary begins the production of estrin—the female sex hormone. The estrin then acts at several points. It is here credited with causing growth in both the uterus and mammary gland. And, though this is not included in the diagram, an earlier paragraph has noted some new evidence that estrin may act on the parathyroid gland—inducing the latter to release its own hormone which in turn causes an increase of calcium in the blood. Notable too is the further fact that estrin shares in psychological effects, particularly in those relating to mating behavior.

Of special interest to this whole story are recent observations of others who report that the initiation of the reproductive cycles of some animals—that is, the seasonally increased release of gonad-stimulating hormone from the pituitary gland—is brought about by so simple a means as the increased amount or intensity of light occurring at that season. And again, that this effect of increased light—the renewed secretion of this hormone—is obtained when this light falls on either the eye, or on the cut ends of the optic nerves, or directly upon the pituitary gland itself.

At cyclical intervals the ovary also produces, in its corpus luteum, a second hormone called progesterone. In general, this hormone is produced in cycles or waves which follow similar waves of in-

creased estrin production. Progesterone acts upon the uterus—inducing there such changes in its lining wall as will enable it to attract and anchor a fertilized egg—and it probably also assists the completion of growth in the mammary gland.

Evidence already considered here has indicated that in certain cases prolactin is able to check or halt the production of gonad-stimulating hormone. Such cyclical interruptions of output of this hormone by prolactin would of course bring cyclical depressions of estrin production by the ovary. Our own view concerning the next very complicated phase of this story is that for a longer or shorter period progesterone will continue to be secreted under the same conditions which interrupt and restrict the ovary's production of estrin. It must be further noted, however, that there is much evidence that luteinizing hormone either shares or assumes full responsibility for a sustained production of progesterone in the ovary.

The rôle of prolactin in stimulating the prepared mammary gland to milk secretion is here indicated. Estrin and progesterone were required to develop the mammary tissue; and, for the initiation or maintenance of milk secretion by this tissue—or perhaps for the adequate supply of precursors of milk in the blood—it is probable that the cortex of the adrenal gland supplies a further necessary product. Finally, it is here indicated that a posterior lobe hormone, which has most extraordinary power to cause uterine muscle to contract, may share in the task of completely emptying the uterus at birth.

III

The quite modern elucidation of the endocrine control of the mysterious mechanisms of reproduction constitutes one of the most significant things that man has learned concerning his own existence. These highly complicated and closely interrelated mechanisms have seemed rather obviously beyond the range of control by nerves and brain. They are so eminently adaptive in nature, they involve such cycles of whirling adjustment in the individual life, and they are so basic to the perpetuation of the species, that some biologists and many others have been tempted to suppose that, though naturalism rules in many compartments of the living world, precisely here is a sphere for vitalism—for an unevolved or supernatural force. The foundations for such conjectures have been shaken and dislodged by hard won disclosures of the laboratories—by the patient uncovering of a hormonal basis for interconnected mechanisms which hitherto seemed complicated beyond our comprehension.

Very impressive too is the fact that the later, fuller growth of the bodies of higher animals and man is under the primary control of the anterior pituitary gland. It has been observed that prolactin and thyrotropin synergize body growth in the dwarf mouse. Very important in this general question is the observation that prolactin alone seems to have proved itself capable of causing good growth, along with increased appetite, in pigeons and doves; also that, in these species, the use of thyrotropin, free from prolactin not only does not make them grow but usually results in rather marked loss of body weight. Again, it is evident that gonad-stimulating hormone directly induces growth in the sex glands; indirectly, through the hormones of the sex glands, it causes further growth throughout the reproductive system, modifies secondary sex characters generally and probably affects still other bodily functions. These and other facts lead us to the view that most or all of the products of the anterior pituitary promote bodily growth not only locally but in one or another species—and this largely through their ability to rouse appetite and to keep

vital organs such as thyroids, adrenals, pancreas, liver and intestines in favorable functional states. Personally I am also impressed with evidence that a particular hormone or combination of hormones that is most favorable to body growth in one species is not the combination most favorable to body growth in another species or perhaps in another individual. In short, to us it seems that the growth response to a particular hormone is also modified or limited by a constitutional factor. These views, however, are contrary to hitherto prevailing opinion which credits the anterior pituitary with the production of a single specific "growth" hormone capable of promoting and prolonging bodily growth. Whatever the outcome of the still unsolved problems concerning the precise way or ways in which the pituitary guides and controls our growth it has already been made clear that in some animals prolactin does promote, and in other species thus far tested it does not equally promote, the important processes resulting in bodily growth.

IV

But this discussion ends. In rather more than one sense the anterior pituitary gland is a close and warm associate of the brain. It too is General Headquarters for a diversified system of structures and products dedicated to the great task of regulating and integrating many complicated processes of the living body. From its site there at the very base of the brain it releases to the blood at least three hormones which are essential to the now known story of what the single product—prolactin—does. First, gonad-stimulating hormone which supplies driving power to the growth and functioning of the reproductive system; albeit this product of the basophilic cells can sometimes be stopped or frozen at its source by prolactin—a product of neighboring eosinophilic cells. With the onset of this particular effect of prolactin one may figuratively say that from this small island at the base of the brain the chill of atrophy and inaction spreads to the reproductive organs throughout the body. Second, from this bit of pituitary tissue there is also formed thyrotropin which, in certain cases at least, reinforces and synergizes the action of prolactin on such processes as heat production and bodily growth. Third, prolactin. To the touch of prolactin itself one further observes that such organs as liver, intestine, crop-sac and mammary gland quickly respond by growth or by secretion; also that, though several hormones may influence the disposition of protein, sugar, glycogen and fat, prolactin is probably one of these effective agents; and finally that this hormone shares in building the broody or maternal instinct—thus forming one link of a chain that binds body and brain together.

WHAT IS GRAVITATION?[1]

By Dr. PAUL R. HEYL

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LET it be said at the outset that it is no more possible to-day to answer the question "What is gravitation?" than it is possible to answer the similar question, "What is electricity?" Nevertheless, it may be interesting and profitable to set forth what is known about this mysterious and omnipresent force and to review some of the many attempts that have been made to explain it.

A scientific hypothesis, to be acceptable, must take account of both positive and negative evidence relating to the phenomenon which it attempts to explain; that is, the hypothesis must not only account for everything which is observed to take place, but must also be careful not to indicate the presence of anything which is known to be absent. The latter task is the more difficult of the two, and since in the case of gravitation there is much more negative than positive evidence the explanation of this phenomenon is particularly difficult.

What are the known facts about gravitation?

First, as to the mathematical law which gravitation follows. In common with other phenomena in three-dimensional space (light, sound, radiant heat, electrical and magnetic forces) the intensity of gravitation varies inversely as the square of the distance. Since this law is common to so many different phenomena it can not be regarded as characteristic of any, and is not likely to afford a clew to their different natures. As is easily seen to be the case in sound, so with the others; the inverse square law must be regarded merely as the expression of the geometrical fact that the area of a sphere is proportional to the square of its radius.

The best evidence for this law is astronomical, because of the great length of time available for cumulative observation. A very small departure from this law would make itself evident in the motion of the planets after a century or two, and yet only once since Newton stated this law has its accuracy been seriously questioned.

In 1845 Leverrier called attention to the fact that the planet Mercury showed a slight irregularity in its motion, inconsistent with the law of inverse squares and too large to be explained as an error of observation. This discrepancy has been confirmed by later observations, and the seriousness with which it has been generally regarded is shown by the attempts that have been made to explain it on the basis of Newton's law.

All such attempts were failures. It is true that the assumption of a belt of diffuse attracting matter surrounding the sun equatorially might account for this irregularity on the part of Mercury, but such matter, in quantity sufficient to produce this effect, would undoubtedly be visible.

All such attempts having failed, the radical proposal was made to alter slightly the Newtonian law by changing the exponent 2 to 2.000,000,1612. This suggestion was made by Asaph Hall,[2] the discoverer of the satellites of Mars, and for a time it received the favorable consideration of no less an authority than

[1] Publication approved by the director of the National Bureau of Standards of the U. S. Department of Commerce.

[2] *Astronomical Journal*, 14, 1894–95, pp. 49–51.

Newcomb, who abandoned it only after E. W. Brown[3] showed that the motion of the moon would not allow of even this slight departure from the whole number 2. The anomalous motion of Mercury thus remained an unexplained puzzle.

For small distances between the attracting bodies, laboratory experiments with the torsion balance show that the inverse square law holds good for distances as small as ten or fifteen centimeters. The precision of such work is at present about one part in 3000.

The acceleration caused by gravity is the same for all bodies. Newton,[4] by experiments with pendulums of equal length but with bobs of different materials found the time of swing constant to about one part in 1000. Bassel[5] carried the precision of this experiment to one part in 60,000 without finding any positive result. It is worthy of note that among the substances tested by Bessel were meteoric iron and meteoric stone.

The most precise work of this character is that of Eötvös[6] and his collaborators, who by an ingenious modification of the torsion balance succeeded in pushing the precision to six parts in a billion (10^9). The substances tested by them form a considerable list, including copper sulphate both in the solid state and in solution, thus furnishing evidence as to change of state. They also tested a mixture of substances before and after a chemical reaction had taken place between them, and in addition worked with radioactive material. The results were negative in all cases.

The question of a possible effect of temperature on gravitation was investigated by P. E. Shaw.[7] He at first believed that he had obtained a small positive result, which he later found to be due to experimental error. His final conclusion was that gravitation is independent of temperature to two parts in a million per degree Centigrade.

Astronomical evidence on this point is furnished by certain short period comets. As these bodies approach the sun they must arise considerably in temperature, and if this has any effect on gravitation their orbits should be altered considerably. But since these comets return time after time with no displacement other than can be accounted for by the influence of the planets near which they pass, the temperature effect must be non-existent. Because of the great rise of temperature in such cases, many times that which can be applied in laboratory experiments of this character, the precision of this result must exceed that obtained by Shaw.

The possibility that crystals of the non-isotropic systems might exhibit gravitational anisotropy has not gone unrecognized. In the early days of the National Bureau of Standards the suggestion was made that the fundamental standards of mass should be made of quartz. Dr. Stratton, the Bureau's first director, made weighings of quartz crystals in different positions, with negative results. This work was never published. Other investigators,[8] working with quartz and calcite, obtained negative results also.

About fourteen years ago this question was taken up again at the National Bureau of Standards,[9] using large crystals of the order of 1kg, and representing all the five non-isotropic systems. A precision of one part in a billion (10^9) was reached, and the results were negative.

[3] Encyc. Brit., XI edition, article "Gravitation."

[4] Principia, Book III, Prop. VI.

[5] *Annalen der Physik und Chemie*, 25–26, 1832, pp. 401–411.

[6] Eötvös, Pekar and Fekete, *Annalen der Physik*, 68, 1922, pp. 11–66.

[7] Shaw, *Nature*, Apr. 8, 1922, p. 462. *Proc. Roy. Soc.*, 102, Oct. 6, 1922, p. 46.

[8] Mackenzie, *Physical Review*, 2, 1895, p. 321. Poynting and Gray, *Phil. Trans. Roy. Soc.*, A, 192, 1899, p. 245.

[9] Heyl, *Scientific Papers of the Bureau of Standards*, vol. 19, no. 482, Feb. 16, 1924.

Dr. Louis A. Bauer, of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, weighed pieces of steel in a magnetized and an unmagnetized condition with negative results. This work was not published.

The question of a finite speed of travel of gravitative action was discussed by the astronomers of the early nineteenth century, and the conclusion was reached that because of the absence of any perceptible aberration of gravitation its speed of travel, if not infinite, must be many times that of light. There is, however, a tradition that Laplace once started to read a paper on this subject before the French Academy, but after a few sentences stopped, put the paper in his pocket, and saying, "I must consider this farther," left the platform. He probably saw what should have been seen before, that gravitation is not a one-way proposition like light. The earth attracts the sun just as strongly as the sun attracts the earth, and no definite direction can be assigned to the propagation of gravitational action.

But the most characteristic (and possibly the most significant) thing about gravitation is the absence of any screening effect. Many bodies are partially or wholly opaque to light, heat or sound; electric or magnetic forces may be greatly reduced or cut off entirely by interposing a suitable screen, but there is no known screen for gravitation. This can mean only that gravitation, unlike the other phenomena mentioned, is not dependent upon the nature of the intervening medium. In this respect gravitation stands apart from all other physical phenomena save one only, and this one, as we shall see, furnished Einstein with a starting point for his theory of gravitation.

Laboratory work on this point has been carried out, that which has attracted the most attention being that of Majorana.[10] He reported a small positive result which, however, seemed to grow less at every repetition of his experiment. So great are the practical difficulties of such work that a result of the order of magnitude reported by Majorana might easily be accounted for by experimental error.

The best evidence for the absence of gravitational screening is astronomical, and because of the large scale of the phenomena involved and the length of time available for cumulative observation the precision of such evidence is high. For example, one may use the whole earth as a screen and consider what would happen at every eclipse of the moon if there were any gravitational screening. If at such times the solar attraction on the moon should be cut off by an amount as small as that reported by Majorana, the moon would recede slightly from the earth, and this effect would become evident in a few years.

If it be argued that the gravitational shadow of the earth may not reach as far as the light shadow, we may consider the evidence furnished by the tides. The attraction of the moon produces a tide on the side of the earth opposite to the moon as well as on the side facing it, and it has been shown by Russell[11] that an absorption of one five-thousandth of that announced by Majorana would show itself as a perceptible irregularity in the tides.

In this case we have also the evidence of astronomical clocks. Some years ago the Lick Observatory claimed to have found a small difference in the rates of their clocks as between noon and midnight. The records of the U. S. Naval Observatory do not confirm this, results over a period of fifteen years showing no

[10] Majorana, Atti della Reale Accademia dei Lincei, 28, 1919, pp. 160, 221, 313, 416, 480; 29, 1920, pp. 23, 90, 163, 235. *Phil. Mag.*, 39, 1920, p. 488.

[11] Russell, *Astrophysical Journal*, 54, 1921, p. 334. Eddington, *ibid*, 56, 1922, p. 71.

effect as great as one tenth as that claimed by the Lick astronomers. The precision of the Naval Observatory results would limit gravitational absorption to about one hundredth of the amount claimed by Majorana. We may therefore conclude that there is no substance on or in the earth in quantity sufficient to exercise any gravitational screening.

We may now appreciate with what an intractable phenomenon we have to deal. Gravitation appears to be a function of nothing but the masses involved and their space coordinates. As to all other properties, the evidence is negative, in most cases of a high degree of precision, reaching a few parts in a billion. The cause of gravitation is hidden in a protective armor on which there is not even a projection upon which to hang a hypothesis. Yet there have been many guesses at a possible cause, and it may be of interest to review some of these briefly.

The earliest of these speculations that can be ascribed to any definite authority is that of Aristotle. This philosopher was content to explain the falling of bodies by ascribing to them a property of "heaviness," and because he observed that smoke and other vapors rose rather than fell he ascribed to them a property of "lightness," thus dividing all bodies into two classes with a sharp line of distinction between them. The idea that the rising of smoke in air might be a parallel case to the rising of wood in water apparently never occurred to him.

So great was the influence of Aristotle upon human thought that this particular error lasted in the minds of some persons until the eighteenth century. It played an important part in the invention of the balloon by the Montgolfier brothers. These had observed, like Aristotle, the rising of smoke and the floating of clouds, and they reasoned that if they could enclose sufficient smoke in a bag the "lightness" of the smoke would carry the bag upward with it. That they had no thought of the part that hot air might play in this experiment is shown by the fact that the fuel they used for their first fire balloon was chopped straw, a material rather inconveniently bulky, but one which produced much smoke. After the success of their first experiments the true cause of the ascent of their balloon was pointed out by the physicist Charles, who suggested the use of hydrogen in later trials.

Another error was made by Aristotle when he stated that heavy bodies fell with speeds proportional to their weights. Though he might easily have checked this erroneous conclusion by experiment he does not appear to have done so, and so great was his authority that this doctrine was generally accepted by those in authority up to the time of Galileo, in spite of the recorded experiments to the contrary of a number of skeptics, antedating Galileo.[12]

But neither Aristotle nor Galileo nor any intermediate student of Nature seems to have advanced any hypothesis as to the ultimate cause of gravitation. Newton himself, as he says in his "Principia," purposely avoided this; but though he "framed no hypotheses" in his formal and official writings, his letters show that privately he speculated freely, as every scientific man should. There is extant a letter from Newton to Boyle in which it is suggested that the attraction of bodies toward the earth might be due to a change in the density of the ether at different levels above the earth's surface.

Among the many suggestions made since Newton there are a few that it may be of interest to consider. One of the most notable of these is that put forth by Le Sage of Geneva in 1750.

Imagine two circular plates to be held parallel to each other in a hail storm. If the storm is so violent that the stones

[12] Lane Cooper, "Aristotle, Galileo and the Tower of Pisa," Cornell University Press, 1935. Heidel, "The Heroic Age of Science," p. 187. Baltimore, 1933, Williams and Wilkins Co.

may be assumed to come from every direction it will be seen that the two plates will to a certain extent shield each other's inner faces from the impact of the stones, and the closer the plates are to each other the greater will be this shielding. As a result, the two plates will be pushed together by a force which will increase as the distance between the plates is lessened.

Le Sage imagined the universe to be filled with what he called "ultra-mundane corpuscles" flying about in all directions with high speeds, like the molecules of a gas, and pushing together any pieces of matter that happened to be close enough to each other. The obvious objection to this theory is the heating effect of these impacts, and a source of continuous supply for the energy, but it is to be remembered that at the time this hypothesis was put forward the conservation of energy was as yet unrecognized.

Another objection to this theory is that according to it a closed box should at least partially shield particles of matter within it from gravitational action. Gravitational screening, however, was as completely unthought of in the eighteenth century as was the conservation of energy.

We find in Le Sage's hypothesis a concept which has held its own in every later suggestion that has been made as to the cause of gravitation, namely, that gravitation is a push rather than a pull. Lodge,[13] in a lecture entitled, "The Ether and its Functions," makes use of this idea in discussing electrical attraction. He points out that it seems to be a natural tendency of the mind to account for the unknown cause of an attraction by calling it a pull, while in those cases which we have learned to understand we find that it is rather to be described as a push. When a horse, as we say, "pulls" a wagon he really pushes against the horse collar; and when we "pull" a door shut we put our fingers on the other side of the knob and push. The same thing occurs in human relations. When we see some one getting along better than we do, we sometimes superficially account for his success by ascribing it to "pull," while a more intimate acquaintance with the facts will generally show it to be a case of "push."

Le Sage's hypothesis attracted wide attention, and its influence is to be seen in many of the hypotheses which followed it. If we imagine the number of these ultra-mundane corpuscles increased until they pass from the state of a swarm of discrete particles to that of a stream in a fluid, we have the fundamental idea which was repeatedly set forth in one form or another during many succeeding years, and which is still occasionally proposed to-day. The Smithsonian Annual Report for 1876 contains an article by W. B. Taylor, giving a summary and criticism of some twenty-five or thirty hypotheses of this nature. The definite shaping of the concept of the luminiferous ether in the nineteenth century had much to do with the growth and spread of such ideas, but to all such suggestions the non-existence of gravitational screening is a fatal objection. It is conceivable that such streams might penetrate the structure of solids, but not without some reduction in velocity, else the body penetrated would not be subject to gravitation. And any reduction in the momentum of the stream must show itself in a corresponding reduction of gravitative force on the other side of the screen.

A new turn was given this idea that gravitation was due in some way to ether motion when Kelvin[14] in 1867 suggested his famous hypothesis of vortex atoms. When this theory was proposed the question that came at once to the mind of every one was, "Will these atoms gravitate?" It was not at first apparent whether they would or would not, and a

[13] Lodge, *Nature*, Jan. 25, 1883, p. 305.

[14] Kelvin, *Math. and Phys. Papers*, vol. 4.

long and difficult mathematical analysis was required before this question could be answered. Maxwell expressed the hopes and doubts of the time in the article "Atom" which he wrote for the ninth edition of the Encyclopedia Britannica in the 1870's, in which he said, "It may seem hard to say of an infant theory that it is bound to explain gravitation." Such, however, was the case. The searching mathematical examination to which the theory was subjected, largely at the hands of J. J. Thomson, failed to indicate any possibility of mutual attraction between these atoms, and Kelvin finally admitted that his hypothesis must be abandoned.

But hope springs eternal in science as elsewhere, and in a few years a new and promising suggestion appeared. It was discovered experimentally that oscillating or pulsating bodies immersed in a fluid medium such as air or water would under certain circumstances attract each other, and under others repel. At once the question of vibrating atoms in the ether suggested itself. This was given serious study by Karl Pearson[15] in 1889, but he later abandoned this line of attack for another which seemed to him more promising. This was his theory of "ether squirts."[16]

It had been observed that a source in a fluid medium, such as the end of a hose turned on under water, would under certain circumstances attract a similar source. Pearson followed up the hydrodynamics of this problem, and found that not only would two such sources attract each other, but that two sinks, where fluid disappeared, would also attract, while a source and a sink would mutually repel each other.

Pearson suggested that an atom might be a source in the ether at which ether was continually generated, perhaps being poured in from somewhere outside in the fourth dimension, or conversely it might be a sink at which ether disappeared. If the ether was incompressible, as was generally held, and space was full of it, it followed that matter, to exist at all, must be found in equal and opposite quantities of the two kinds. To account for the fact that but one kind is known to us, Pearson suggested that in the course of ages the two kinds had separated by their mutual repulsion, and that somewhere in the distant reaches of space there might be found a universe of the opposite type of matter, a counterpart of our own. Whether this would be of the source or sink variety it was of course impossible to say.

In the discussion evoked by this hypothesis there was cited the instance of a certain star (1830 Groombridge) which possessed the greatest proper motion then known, a velocity so great that it could not have been produced by the attraction of all the known matter in the universe, acting at the distances involved. It was suggested that this velocity might have been produced by repulsion, the star having been at one time much nearer our system.

Against this theory of gravitation there is to be considered the omnipresent objection of gravitational screening, which would entirely vitiate the hydrodynamical reasoning upon which Pearson founded his hypothesis. It is to be said, however, that the full force of the evidence for the absence of gravitational screening was not recognized until the twentieth century.

The next hypothesis of importance came from Osborne Reynolds.[17] In its way it was as original as that of Pearson, for it involved a complete inversion of our ideas of the structure of the universe.

[15] Pearson, *Camb. Phil. Trans.*, 14, 1889, p. 71; *London Math. Soc. Proc.*, 20, 1889, p. 38, 297.

[16] Pearson, "Ether Squirts," *Amer. Journal of Mathematics*, 13, 1891, pp. 309–362.

[17] Reynolds, "The Sub-Mechanics of the Universe," *Sci. Papers*, vol. 3.

Reynolds supposed the ether to have a fine-grained structure such as might result from some process akin to the piling of shot. He further supposed there to be cracks or irregularities in the piling. These empty spaces or cracks in the substratum of the universe Reynolds regarded as the atoms of matter.

He was able to show that under pressure there would be a tendency for two such cracks to approach each other, thus satisfying gravitational requirements. It can be seen, however, that if two cracks were separated by a large completely empty space, corresponding to a thick and very dense piece of matter, while there might be a tendency for both cracks to approach the empty space, the latter would effectually prevent any action of one crack on the other across it. In other words, the objection of gravitational screening again interposes itself.

More theories of gravitation have foundered upon this rock than upon any other. A whole class of hypotheses is ruled out by the screening objection, namely, all electro-magnetic theories.

Every electrical or magnetic action is capable of being screened, partly or wholly, and it is impossible to conceive of any electro-magnetic combination which will not be subject to screening in one or both of its elements. The burden of proof rests upon the author of such a theory to show that the screening objection does not hold. Many such theories have been proposed, suggested probably by the similarity of the inverse square law in each case, but in none of these hypotheses is it specifically pointed out how the screening objection is to be avoided. In fact, one comes from the study of such hypotheses with the impression that their authors either ignore this objection or are ignorant of it.

Thus at the end of the nineteenth century our knowledge of gravitation, in its positive aspect, stood just where Newton had left it. Much experimental work had been done in the hope of showing some relation between gravitation and other physical phenomena, but the results had been all negative. Gravitation seemed to hold itself aloof from other phenomena, steadily refusing to acknowledge any kinship to what were strongly suspected of being its relations. Yet optimism prevailed, and hope was maintained that gravitation would yet be brought into line with other phenomena of Nature.

But like Moses of old, the physicists of the nineteenth century might look ahead over the promised land, but might not enter. It was reserved for Einstein in the twentieth century to make the first positive step toward the correlation of gravitation with other phenomena of Nature. All the facts concerning gravitation were well known to Einstein, who pondered over them, set them in perspective, and by his genius was able to evolve from them a suggestion as to the nature of gravitation which, while not perfect, is the first positive advance that has been made in the subject since the time of Newton.

I have said that gravitation stood for a long time in a class by itself among physical phenomena. In so far as this is true, it was due to the short sight of the observers, for Einstein pointed out that there was another phenomenon of very much the same kind, namely inertia, in the form known as centrifugal force. Centrifugal force is independent of the material, is not a function of the temperature and can not be cut off by any form of screen. In fact, centrifugal force, like gravitation, seems to be a function of nothing but the mass involved and its space and time coordinates.

Einstein illustrates this by means of a revolving disk. Imagine such a disk capable of carrying an observer, such as may be seen in amusement parks. Let the disk be covered by a dome which revolved with it, so that the observer within

can not tell by direct observation of other bodies whether or not the disk is in rotation. Suppose the disk is at first stationary. The observer, in walking from one point to another of his little world, would perceive no difference at the different points; but let the disk be set in rotation, and though the observer could not directly perceive the motion he would become aware of a certain difference. At every point of his space except the center he would experience a force repelling him radially outward, and the greater the distance from the center the greater the force of repulsion. He would, in fact, be in a sort of turned-inside-out gravitational field of force.

With our superior knowledge we recognize this "force" of repulsion to be purely inertial in its nature. As such, it does not originate at the center of the disk, but in the observer himself, and consequently no screen erected between him and the center can diminish the force he feels. Here we have an illustration of how the motion of a system may give rise to something remotely simulating a gravitational field which disappears when the motion of the system stops.

Another illustration that may help us in this connection is that of an elevator. Imagine an elevator with closed walls, containing an observer. Suppose the elevator at first at rest. Let a bullet be fired through it horizontally. The path of the bullet to the observer within will appear as a straight line from wall to wall. If the elevator be moving upward with constant speed, the path will appear as a straight line slanting downward. But if the upward motion of the elevator be accelerated, the path of the bullet will no longer appear straight, but as a curved trajectory, convex upward.

The observer might account for this curved path by saying that the bullet moved according to the resultant of two forces: its original impulse, which would cause by itself a straight path from wall to wall, compounded with another force of attraction of some unknown nature, drawing the bullet downward toward the floor of the elevator. This is assuming a force which does not really exist, and which in consequence may be expected to be rather difficult to explain. What has actually happened is that the observer has changed from fixed to moving coordinates.

Imperfect as are these attempts to represent the actual gravitational field of a body, they may nevertheless help us to understand what Einstein means when he says that a gravitational field is equivalent to an inertial field produced by a suitable change of coordinates; yet neither of these illustrations furnishes us with a change of coordinates adequate to the representation of the actual three-dimensional field of a material particle. The task of finding such a coordinate system, if indeed any should exist, might well appall the best equipped of mathematicians; yet with sublime confidence in his intuition it was to this task that Einstein set himself.

And then a wonderful thing happened, for with but the slenderest of clues, and guided principally by what we may fairly call the intuition of genius, he succeeded! He found a transformation of coordinates which represents a little more accurately than Newton's law the physical phenomena concerned on gravitation.

Imagine a smooth flat frozen surface of a lake. Assuming friction to be absent, a stone set in motion on this surface would move in a straight line with uniform velocity, obeying Newton's first law of motion. If we observed the path of the stone to depart from a straight line at any point we might reasonably infer that there was a slight elevation or depression of the ice at that place. Suppose there to be a large, heavy stone resting upon the ice, producing a rather

deep and widely extended depression or cusp in the surface. At some distance from it, where the ice is again flat, suppose a small stone, which produces no appreciable cusp, is set in motion in such a direction as will carry it past the heavy stone at a short distance from it, well within its cusp. The path of the small stone, at first a straight line, will, as it enters the cusp, gradually assume a curved form. Assuming no attraction to exist between the large and the small stone, the latter will pass on and out of the cusp, its path again becoming straight; but on account of the brief twist to which it was subjected the latter portion of the path will not in general be in the same straight line as the first. The small stone will have suffered a deflection.

An observer watching the motion of the small stone through what we may call Newtonian spectacles, which do not show him the curvature of the ice, will say, "Yes; on passing the large stone the small one seems to have experienced a force of attraction which has deflected it from its straight path." But let him replace these glasses by others of Einsteinian make, and he will say, "No, I see now that there was no force of attraction at all. It was purely the inertia of the small stone combined with the curvature of the surface which it had to traverse that produced the change in its path."

If the small stone passed very close to the large one it might not be able to get out of the cusp at all, but would circulate round and round, describing a curve whose shape would depend on that of the cusp and on the plane of motion of the small stone. If the cusp were shaped somewhat like that around the stem of an apple, the path of the small stone might be an ellipse which failed to close, and would resemble the actual orbit of the planet Mercury.

So much for a two-dimensional surface curved in a third dimension. Einstein's explanation of gravitation contemplates an analogous phenomenon in a space of more than three dimensions. A ray of light coming from a star traverses space for millions of miles remote from material bodies, and consequently "flat." Through this region the path of the ray is a straight line. But if it eventually passes close by the sun, whose great mass causes a considerable cusp or warp in our solid space, the path of the ray becomes twisted, and when it again becomes straight it has been permanently deflected from its original course.

Concepts such as these are apt by their strangeness and transcendental character to cause us to lose the true perspective of the situation. The theory of relativity is but a working mathematical hypothesis, designed to cut a little more closely to the line than that of Newton. But it is still artificial in its nature, and is by no means to be regarded as the ultimate representation of the truth of Nature.

The theory of relativity has done much. It has explained one astronomical phenomenon for which Newton's law of gravitation was found to be inadequate. It has successfully predicted two new physical phenomena. And yet, when it comes to such apparently simple matters as rotational motion and centrifugal force, the theory, as Eddington says, stops explaining phenomena and begins explaining them away.

Einstein himself regards this child of his brain quite sanely. Being a mathematician, he naturally recognizes an empirical equation fitted to a curve as something totally different from the real equation of the curve, and bound to diverge from it if carried out far enough. "No amount of experimentation," Einstein is reported to have said, "can ever prove me right. A single experiment may at any time prove me wrong." Not

that any one has at present a better theory to suggest; but such a thing doubtless will come to pass when the hour and the man arrive. Newton cut so closely to the line that over two centuries elapsed before Einstein could better his formula; and how long it will be before the next corrective term is added to the empirical equation for the great curve of Nature is a matter at present on the knees of the gods.

We have now seen the physical facts, positive and negative, which must be satisfied by any theory of gravitation, and we have reviewed the most important hypotheses which have been proposed to explain these facts. What is the conclusion of the whole matter? Is there anything in all this theorizing that can be considered of permanent importance?

There is at least one concept which, as we have seen, is to be found in practically all gravitational hypotheses from LeSage to Einstein, namely, that gravitation is a push rather than a pull. There is weighty evidence to support this view in the absence of gravitational screening, which must mean that gravitation does not depend in any way upon the nature or condition of the intervening medium, through which a pull would have to be transmitted.

There is also a second idea which may figure largely in future speculation. We have seen it hovering vaguely in the background of Pearson's hypothesis, and have found it faced frankly and stated explicitly by Einstein, namely, that a satisfactory explanation of gravitation transcends the limitations of Euclidean three-dimensional space. Radical as this may seem, it can not be denied that after two centuries of fruitless theorizing the introduction of hyper-geometry brought about the first positive advance in the subject of gravitation since the time of Newton.

The more we study gravitation the more there grows upon us the feeling that there is something peculiarly fundamental about this phenomenon to a degree which is unequaled among other natural phenomena. Its independence of the factors which affect other phenomena, its dependence only upon mass and distance suggests that its roots avoid things superficial, and go down deep into the unseen, to the very essence of matter and the space in which it lives and moves and has its being.

GROUP THEORY IN THE HISTORY OF MATHEMATICS

By Professor G. A. MILLER

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IT is well known that the ancient Babylonians theoretically used the same symbol for every number of a geometric progression whose common ratio is 60. In particular, they theoretically used the same symbol for every number contained in the infinite series

$$\ldots \quad \frac{1}{216000} \quad \frac{1}{3600} \quad \frac{1}{60} \quad 1, \; 60, \; 3600, \; 216000, \; \ldots$$

As this particular series constitutes an infinite group with respect to multiplication it results that their wedge number symbol, which also represented unity, is the oldest known symbol which was used for a long time to represent an infinite group. Hence this particular group may be said to constitute the basis of their numerical notation. The infinite series of numbers which were constructed similarly by multiplying the terms of this series by the positive integers from 2 to 59 inclusive obviously do not separately constitute a group with respect to multiplication, since they do not include unity.

There has been a tendency in the development of mathematics towards greater and greater generality, but the numerical notation of the ancient Babylonians is a striking exception to this fundamental tendency. This numerical notation, which is also practically a positional number system to the base 60, is unique in the history of mathematics. The use of the same number symbol for every term of a geometric progression of numbers is so different from our common modern system in which two distinct numbers are always represented by distinct symbols that it is quite difficult at first to understand why a people who had made so much progress in civilization could be satisfied with a numerical system which seems to have such obvious disadvantages. One of its advantages is that it practically makes the use of common fractions unnecessary, and these were somewhat troublesome in early civilizations.

While the ancient Babylonians used in their common number system the group formed by the terms of a geometric progression which has unity for one of its terms they did not use in this system the more important group formed by the totality of the positive rational numbers. In particular, the unit fractions 1/2, 1/3, 1/4, 1/5, 1/6 were represented in this system by 30, 20, 15, 12, 10, respectively, but the fraction 1/7 did not form a regular number of this system. Their regular unit fractions had no prime factor in their denominators besides 2, 3 and 5. While their number system had many practical advantages in an early stage of civilization it would not be acceptable at the present time. One of its great defects was that it did not involve a symbol corresponding to our modern decimal point. Its existence points to the advantages resulting from an emphasis of the property of similarity. In particular, 10 and 10,000 represent the same amount of money if the unit in the former case is a dollar and in the latter a mill.

In the introduction to his widely used "Theorie der Gruppen von endlicher Ordnung," third edition, 1937, A. Speiser emphasizes the fact that regular geometric figures may have been studied by group theory methods as early as 1500

B.C., and that Egyptian ornaments may have been the objects of mathematical study in ancient times. It is clear that some of these ornaments can not be fully comprehended without a study of the related groups of transformations, but the evidences pointing to the existence of an early group theory among the Egyptians are not yet entirely conclusive. It should also be noted that the fact that the Babylonians actually used an infinite group as a basis of their numerical notation in very ancient times does not prove that they were then interested in the study of group properties. The existence of this group at that time and of a symbol for it are, however, well established.

The group formed by the positive rational numbers when they are combined by multiplication was probably the most potent factor in making the group concept commonplace at the time when Euclid's "Elements" were written so that it did not seem necessary to emphasize this concept in these "Elements." The study of the regular geometric figures by the ancient Greeks presented many opportunities to direct attention to group properties which were not then utilized. In fact, the first figure in Euclid's "Elements" relates to the regular triangle, but its group of movements is not mentioned in connection therewith. This omission may have been largely due to the fact that it was not then known that the subject of group theory has such wide contacts and hence it is now desirable to emphasize its elements whenever a proper occasion presents itself.

In 1898 H. Poincaré published an article in the *Monist* in which he used the following words:

> The principal foundation of Euclid's demonstrations is really the existence of the group and its properties. Unquestionably he appeals to other axioms which it is more difficult to refer to the notion of group. An axiom of this kind is that which some geometers employ when they define a straight line as the shortest distance between two points. But it is precisely such axioms that Euclid enunciates. The others, which are more directly associated with the idea of displacement and with the idea of groups, are the very ones which he implicitly admits and which he does not deem necessary to enunciate. This is tantamount to saying that the former are the fruit of later experience, that the others were first assimilated by us, and that consequently the notion of group existed prior to all others.

Although the group concept had become commonplace at the time of Euclid it took about two thousand years longer to start a vigorous development of this concept and to move it gradually into the foreground of mathematical investigation. This forward movement was started during the latter half of the eighteenth century by various writers, including J. L. Lagrange (1736–1813), who stated explicitly that the order of every substitution group on n letters divides the order of the symmetric group on these letters. He also called attention to various special substitution groups, including the now well-known non-cyclic group of order 4, which has been called recently "Kleinsche Vierergruppe" by various German writers in honor of the outstanding German mathematician, Felix Klein (1849–1925), who used it extensively under its now common German name "Vierergruppe."

To illustrate the fact that honors are sometimes bestowed in a questionable manner in the history of mathematics it may be of interest to mention here some additional facts relating to the name "Kleinsche Vierergruppe." This group, composed of four elements, is the simplest non-cyclic group, and it is represented by the four movements of our ordinary space which transform into itself a given fixed rectangle having two unequal sides. It therefore seems likely that its properties were observed in ancient times already, but it is not now

known when these properties were first recorded. As was noted above they appear explicitly in an article by J. L. Lagrange published in about 1770, which became well known soon thereafter. They appear also in at least one other widely known work, which was published before Felix Klein was born, *viz.*, in the "Exercices d'analyse" of A. L. Cauchy, volume 3, page 252 (1844).

It is, however, more important in this connection to note the fact that this particular group was widely used and explained during the early years of Felix Klein, before he began to publish anything on this subject. In particular, when he was about five years old, the noted English mathematician A. Cayley (1821–1895) published an article in the *Philosophical Magazine* (1854) in which he gave a detailed multiplication table of this group and explained again its properties. It is therefore well established that when Felix Klein began to use this group its abstract properties were widely known. This makes the fact that it is now so often referred to as the "Kleinsche Vierergruppe" more interesting as a historical fact, since it throws light on the significance which should be attached to the naming of things in science in honor of an outstanding man.

Very few groups have as yet received special names. These include the octic group, which is the dihedral group of order eight and corresponds to the dihedral group of order four, which was noted above. Notwithstanding its great simplicity, this group apears under five entries in the second edition of "Webster's New International Dictionary," as follows: "anharmonic group," "axial group," "cross-ratio group," "four-group" and "quadratic group." In Bôcher's "Introduction to Higher Algebra" (1927), it is called the "fours group" as a translation of its German name "Vierergruppe." Since there are two abstract groups of order four and five abstract groups of order eight the terms "four group" and "octic group" fail in themselves to give characteristic information in regard to these groups. We are, however, not so much interested in this connection in the feasibility of giving individual names to individual groups as in the question of the historical significance of assigning names in honor of an individual and in the historical tendency to centralize credits unduly.

During the long period of time extending from the ancient Babylonians to the latter half of the eighteenth century the concept of group entered very gradually into mathematical thinking, and it did not then even receive a special name. Such a name was given to it by J. L. Lagrange in the article to which we referred, but this concept did not attain maturity until a satisfactory definition of an abstract group appeared more than a century later. The word group is an instance of the adoption of a common word by mathematicians to represent a concept which grew rapidly thereafter and became so complex that its definition could not be inferred from the common meaning of its name. Even in the subject itself the common meaning of the terms are often misleading, since the term simple groups is used to represent the most difficult category of groups. When the youthful E. Galois (1811-1832) introduced the word group as a technical term he could not foresee the enormous amount of literature which has since then appeared under this word and is still appearing thereunder.

When E. Galois died he is said to have expressed regrets that he could not have died for his country. The glory which his work on groups has brought to his country through the efforts of thousands who proceeded along lines to which he first called attention seems to be a greater

credit to his country than his death in fighting in her behalf could have been. The facts that his work at first failed to receive due recognition and that he endured many hardships in consequence thereof may have led to a deeper and more sympathetic interest in his work on the part of some of those who later understood its real significance. At any rate, E. Galois has been a very inspiring figure in group theory as well as in the general history of mathematics. Additional evidence along this line was recently furnished by an American publication, entitled "Galois and the Theory of Groups, a Bright Star in Mathesis," 1932. Many mathematicians have expressed surprise because his name does not appear in the "biographical dictionary" of "Webster's New International Dictionary," 1935.

As evidence of the influence of the concrete in the development of modern mathematics it may be interesting to note here that during the first hundred years from the time of J. L. Lagrange's work along this line group theory was developed mainly as a concrete subject, with gradually increasing emphasis on its abstract properties. The permutations or substitutions which were the main objects of group theoretic study during this period are partly abstract, since they do not concern the nature of the objects which are permuted just as one foot does not specify the object measured. It is, however, customary to class one foot with concrete numbers. An occasional movement towards abstract group theory appeared about the middle of the nineteenth century, especially in the work of the English mathematician, A. Cayley, but this movement was not placed on a solid foundation before the appearance of a satisfactory definition of the term abstract group in 1882. Group theory thus furnishes an interesting modern example of the movement from concrete to abstract ideas in the development of mathematics.

THE HISTORY OF THE LICK OBSERVATORY

By Professor CHARLES H. SMILEY
DIRECTOR OF THE LADD OBSERVATORY, BROWN UNIVERSITY

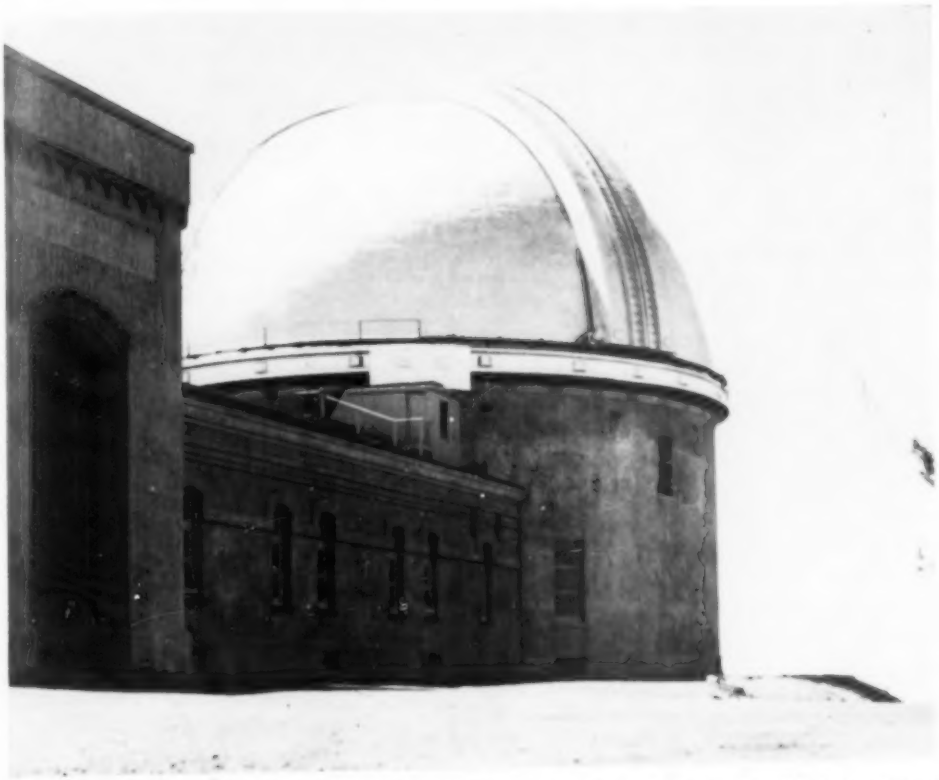
THE Lick Observatory of the University of California was founded through the generosity of James Lick, an eccentric California millionaire. He provided $700,000 for the purchase of land, the construction of buildings and the construction of "a powerful telescope superior to and more powerful than any telescope ever yet made, with all the machinery appertaining thereto and appropriately connected therewith, or that is necessary and convenient to the most powerful telescope now in use, or suited to one more powerful than any yet constructed." No one knows why James Lick decided to provide the money for this observatory. So far as is known, he had never looked through a telescope. Somewhat later, in his "Reminiscences of an Astronomer," Simon Newcomb said that if Lick had looked through a telescope, Lick Observatory probably would never have existed. Lick was apparently a difficult person with whom to get along. He took a dislike to a member of the first board of trustees, and as a result the entire board resigned. A second board was named, and yet again a third, before Lick died and the observatory was finally constructed.

Lick placed several restrictions on the use of his money. One was that the observatory should be erected in California. Another was that he should be buried in the pier which supported the great telescope. If he could clearly have foreseen the future, he probably would not have made the latter provision. In 1927, when the author of this article first went to Lick Observatory, as a graduate student of the University of California, he accompanied another graduate student one evening to the dome of the 36-inch refractor. After a short time in the quiet dark dome, an eerie sound was heard and he called to his friend, "What on earth is that?" "Oh," the friend laughingly replied, "that is just James turning over in his grave." In reality, it was due to a part of the mechanism of the telescope.

In the beginning, Lick wanted the telescope mounted near the edge of Lake Tahoe, but this site was abandoned because of the severe winters in that region. A number of sites, including Mt. St. Helena, Mt. Diablo, Loma Prieta and Mt. Hamilton, were considered before the final decision was made. S. W. Burnham spent two months on Mt. Hamilton in the fall of 1879, observing many double stars with a six-inch telescope before he reported that this would be a satisfactory location for the Lick telescope. This favorable report came as a surprise to Newcomb and other astronomers who had thought that rising currents of air would disturb the "seeing" on a mountain peak. This observatory was the first large one to be located on a mountain top; its success is reflected in the locations of the large reflecting telescopes built in recent years, Mt. Wilson, Mt. Locke, Mt. Palomar.

A congressional grant, made on June 7, 1876, provided 1,946 acres for the observatory site. The state of California gave 511 acres, 703 acres were acquired by purchase or gift and 30 acres were sold, leaving a total of 3,130 acres.

On Mt. Hamilton, there were three peaks: Mt. Copernicus, 4,448 feet, Mt. Kepler, 4,318 feet, and Observatory Peak, 4,302 feet. It was necessary to remove 72,000 tons of material from the



THE SEVENTY-FIVE FOOT DOME OF THE THIRTY-SIX INCH LICK TELESCOPE, THE SECOND LARGEST REFRACTOR IN THE WORLD.

last-mentioned peak to get a level platform large enough for the erection of the main building. Mt. Kepler became the site of the water reservoir, the source of the water being a spring 350 feet below the summit and almost a mile from the observatory. Another spring has since been added to the observatory water supply.

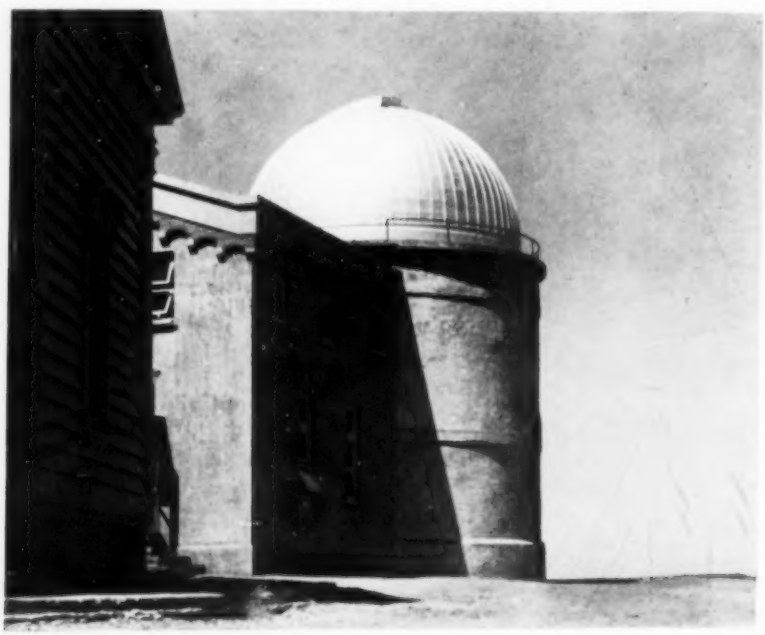
To make the observatory accessible, Santa Clara County completed in December, 1876, a road 22 miles long at a cost of $80,000. This road rises 4,000 feet and at the steepest grade in any part of it, it rises only six feet in a hundred. When one hears that the mountain is only 13 miles by air-line from San Jose and 27 miles by road, one suspects that the road is crooked. In the last seven miles, there are 365 turns, one for each day in the year. Young astronomers working on the mountain have named each of these turns; the very last one before reaching the observatory is called "Oh My" because of the exclamations of visitors as they look out over the precipice into the emptiness of space.

With the coming of the automobile, San Jose was much more accessible to the astronomers. Occasionally on cloudy evenings, some of them drive down to see the movies, returning the same evening. On one occasion, Dr. C. S. Yü, then a graduate student, was driving down the mountain in a small automobile. On one of the turns, the machine turned over, stopping at the very edge of the road. Mr. Yü, uninjured, climbed out to mar-

vel at his narrow escape, then crawled back under his car to get his camera so he could photograph the overturned car. Shortly after that, another machine came along; the occupants helped Yü turn his machine over and watched him drive on down the mountain.

The lens for the large telescope was made by Alvan Clark, after Simon Newcomb, at the request of the trustees, had visited all the leading European glass makers and telescope makers and had reported that the Clark firm was best fitted for the work. He also decided that refractors were most reliable. If Lick had been alive, he would undoubtedly have objected to the awarding of the contract to the Clarks. He had written to Alvan Clark asking how large a telescope might be made and what such a telescope would cost. Without giving the matter careful consideration, Clark had replied, "$200,000." Lick felt that this was much too much and would have nothing more to do with the firm. He did not have a clear idea of the mounting necessary for a large lens. Apparently he felt that a lens hung at the end of a pole would be enough.

After his death, the trustees were free to do things as they felt they should be done. In 1880, the Clarks started work on the large lens. It took seven years to build and cost $50,000, exclusive of the mounting. It was shipped by rail to California in 1886 in a special car with 16 persons accompanying it. Alvan G. Clark went along and stayed on Mt. Hamilton until the lens was in place. For nine years, until the completion of the forty-inch lens of the Yerkes Observatory in October, 1895, it was the largest refracting telescope in the world. Even now, after more than fifty years, it is still the second largest refractor. It was originally planned and constructed for



THE DOME OF THE TWELVE-INCH REFRACTING TELESCOPE OF THE LICK OBSERVATORY OF THE UNIVERSITY OF CALIFORNIA.

THE DIRECTOR'S RESIDENCE AND THE DOME OF THE THIRTY-SIX INCH CROSSLEY REFLECTOR.

visual work; a 33-inch correcting lens was made by the Clarks to adapt it to photographic work.

The mounting was made by Warner and Swasey. It was the first of the many great instruments mounted by them. This firm was also responsible for the 75-foot dome housing the large telescope and for the 60-foot elevating floor. The latter was a novelty then; it has since been copied in many observatories.

At the recommendation of Simon Newcomb, Edward Singleton Holden, then director of the Washburn Observatory of the University of Wisconsin, was chosen to be the first director of the Lick Observatory. A cousin of George P. Bond, of Harvard College Observatory, and son-in-law of William Chauvenet, he had worked for a time as an assistant to Newcomb at the U. S. Nautical Almanac Office. He was made president of the University of California in 1885, holding this position until 1888, when he resigned to take the post of director of Lick Observatory. At that time, he filed a bill for $12,000 for the advice and assistance he had given the trustees while the observatory was being built. This was entirely unexpected, but the chairman of the board of trustees, a diplomatic soul, upon the advice of Newcomb, suggested to Holden that his purpose in filing the bill undoubtedly was to place on record his valuable services in the erection of the observatory. Holden did not disagree with this statement and did not press for payment.

Much of the brilliance of the history of the Lick Observatory can be credited to the good judgment of Holden in picking the men who were to work under him. S. W. Burnham and J. E. Keeler had already established reputations for themselves, while E. E. Barnard, W. W. Campbell and J. M. Schaeberle were later to become outstanding men in the field of astronomy.

Holden's time was largely taken up with administrative duties; his principal research during his time as director was concerned with the making of a splendid photographic atlas of the moon.

In 1895, Edward Crossley, of Halifax, England, gave a 36-inch reflecting telescope to the Lick Observatory. The mirror was made by Sir Howard Grubb and the mounting by Ainslee A. Common. The costs of transporting it from England and of housing it in California were met by popular subscription.

It had been planned that the astronomers and their families were to live on the mountain top. To this end, a schoolhouse was erected and Santa Clara County provided a teacher for the children. In more recent observatories, this arrangement has not been followed. A community isolated on a mountain-top is essentially a small town, with all its disadvantages and inconveniences. This may explain in part some of the unfortunate animosities which appeared during Holden's term as director; the story in its entirety has never been told. In any case, Holden resigned in 1897, retiring to private life. Later he served as librarian at West Point.

He was followed by James Edward Keeler, who had been serving as director at Allegheny Observatory since 1891. Perhaps Keeler's greatest contribution to Lick Observatory was the preparation of the Crossley reflector for useful work and in showing that it could be used in the study of the extra-galactic nebulae. He showed that these nebulae were numerous and that a large proportion of them were of the spiral type. His relatively peaceful term as director ended with his death in 1900.

Keeler was succeeded by the late William Wallace Campbell, who continued as director of the Lick Observatory until 1930, though he was also president of the University of California from 1923 to 1930. Campbell is probably best known for his application of the spectrograph to the study of stellar motions, a field in which he was a pioneer. Many of the outstanding American astronomers of today served an apprenticeship at Lick Observatory and had a part in the gathering of data on stellar radial velocities. To extend this important work to cover the southern hemisphere as well as the northern, friends of the university provided funds for a 37-inch Cassegrain reflecting telescope equipped with several spectrographs, and the erection and maintenance of a station at Cerro San Cristobal, near Santiago, Chile. This southern expedition, originally planned to last for two years, continued from 1903 to 1929, when the Chile station was sold to the Catholic University of Chile. In this program, more than 25,000 spectrograms were made at Mt. Hamilton and Cerro San Cristobal, from which the radial velocities of 2,771 stars brighter than magnitude 5.51 were determined. The apex of the sun's way as determined from these radial velocities agrees very well with the positions previously determined from the proper motions of stars.

Robert Grant Aitken, known internationally for his work on double stars, followed Campbell as director. He continued in this post to 1935, when he was succeeded by William Hammond Wright. Wright is perhaps best known for his work on the use of color filters in the photography of planets, though his work on the spectra of gaseous nebulae and novae is probably at least as important scientifically. It is interesting to note that in the fifty years of existence of Lick Observatory, there have been only five directors. Two of them have served for a time as president of the University of California, and each of the last three has received the Gold Medal of the Royal Astronomical Society.

In a brief article such as this, one could

RESIDENCES, SCHOOL-HOUSE, WATER RESERVOIRS AND SMALL DOME HOUSING CROCKER SIX-INCH PHOTOGRAPHIC TELESCOPE.

not hope to mention all the important discoveries and studies made at the Lick Observatory, nor indeed all the outstanding astronomers who have been connected with it. The omission of a discovery or of an astronomer, it is hoped, will not be construed as reflecting in any unfavorable way on the discovery or the astronomer. One should not fail to point out that of the nine known satellites of Jupiter, four were known to Galileo and four more were discovered at Lick Observatory. About 4,000 visual double stars and about 400 spectroscopic binaries have been discovered there. The dense companion to Procyon whose existence was suspected by Bessel some 75 years earlier was found with the 36-inch Lick telescope. Thirty-three comets, nineteen unexpected and fourteen returns of periodic comets, have been found by Lick astronomers.

Members of the staff have participated in many eclipse expeditions, for which funds have been generously provided by friends of the university, notably Charles F. and William H. Crocker. An expedition was sent to northern California to observe the total solar eclipse of January 1, 1889; another was sent the same year to Cayenne, French Guiana, to observe the eclipse of December 22. Both of these expeditions were successful, as was the next one, sent to Mina Bronces, Chile, for the eclipse of April 16, 1893. The Lick party which went to Japan to observe the eclipse of August 9, 1896, was unsuccessful because of heavy clouds.

It was the party sent to India to observe the eclipse of January 22, 1898, which introduced the moving-plate technique of Campbell. This expedition was successful, as was the one to Georgia for the eclipse of May 28, 1900. May 18,

1901, found another Lick group in Sumatra successfully recording another total solar eclipse, despite clouds which threatened failure.

Of the three parties sent out from Lick Observatory to observe the eclipse of August 30, 1905, the one in Spain had good skies, the one in Labrador was defeated by clouds, while the one in Egypt had poor seeing. In 1908, Lick astronomers saw the eclipse of January 3 from Flint Island, a coral atoll in the South Pacific.

The expedition to Kiev, Russia, for the eclipse of August 21, 1914, was probably the least favored of all; clouds spoiled the eclipse and the outbreak of the European war impounded the eclipse equipment. It was only with difficulty that the observers themselves were able to get back to the United States. For the eclipse of June 8, 1918, a Lick party went to the state of Washington, where their observations were successfully made.

The eclipse of September 21, 1922, stands out among the Lick expeditions, since it was the photographs taken by the Lick party in Australia which provided one of the few successful verifications of the deflection of light by the sun's gravitational field in the amount predicted by Einstein.

The Lick expedition to Lower California for the eclipse of September 10, 1923, was unsuccessful because of weather conditions. On April 28, 1930, and August 31, 1932, total solar eclipses were successfully observed in California and at Fryeburg, Maine, respectively. One may be reasonably certain that Lick parties will observe important eclipses of the future and that friends of the university will

THE MT. HAMILTON ROAD, NEAR THE OBSERVATORY.

continue their generous support of such expeditions.

It will be noted that no mention has been made here of the splendid work carried on at the Students Observatory of the University of California at Berkeley under the direction of Dr. A. O. Leuschner. Another article would be needed even to sketch the achievements of this branch of the astronomy department of the university.

To bring the story of the Lick Observatory up to date, something must be said of the new photographic telescope now under construction. In 1934, the Carnegie Corporation of New York made a gift of $65,000 to the observatory to pay for a 20-inch photographic refractor. It was planned that this telescope should cover a field in the sky six degrees in diameter and record stars as faint as the nineteenth magnitude in a two-hour exposure. The design of the lens was made by F. E. Ross; its construction has been placed in the hands of J. W. Fecker, of Pittsburgh.

The specific problems proposed for study with this new instrument are the rotation of the galaxy as evidenced in the motions of the very faint stars and the distribution of the faint extra-galactic nebulae. If the next fifty years finds the new telescope being put to as good use as the thirty-six inch Lick refractor and the thirty-six inch Crossley reflector have been in the last fifty years, no one will deny that the money has been well spent.

In conclusion, the author wishes to acknowledge his indebtedness to many sources of information, in particular, to his friends at the Harvard College Observatory. It is hardly to be expected that an article such as this, dealing with recorded history, will be highly original; the most that one can hope is that it be reasonably accurate and not too biased.

A METEORITE SURVEY

By Dr. H. H. NININGER
DENVER, COLORADO

FUNDAMENTALLY, rocks may be divided into two groups—*Accretionary* and *Terrestrial*. The former have arrived from space recently enough so that their structure and composition are predominantly those that characterized them extra-terrestrially. In the latter the characteristics are mainly those which have been acquired through an interaction of terrestrial forces.

The discovery that matter falls to the earth from space is a comparatively recent one. The earliest scientist to advocate such an idea seems to have been Chladni, who published a treatise setting forth this belief in 1794. The hypothesis was soon after verified by witnesses to such arrivals, the shower of stones at L'Aigle, France, in 1803, constituting the most undeniable demonstration of the fact.

From the earliest discovery of meteorites they were regarded by scientists as being qualitatively of primary importance, and their structure and composition were investigated with utmost care. Only their scarcity and consequent high valuation were allowed to interfere with the most exhaustive analyses of their contents.

Quantitatively, meteorites received very little attention. There were those of course who realized the possible importance of the increment of cosmic material, and Lockyer went so far as to present in a very elaborate form the meteoritic hypothesis as the method of stellar and planetary evolution. His approach, however, was purely hypothetical and was not accompanied by any convincing body of factual evidence. Apparently the hypothesis has never been taken very seriously by the professions of astronomy and geology.

In 1873 Proctor had suggested that the lunar craters may have resulted from the impact of large meteorites or asteroids. G. K. Gilbert later (1893) elaborated on this idea and depicted in detail how the structure of the lunar craters conformed to what might be expected from such impacts. However, when he came to apply this hypothesis to the Arizona impact crater then known as "Coon Butte" he rejected his own hypothesis pronouncing this great landmark the result of a steam explosion, and staunchly defended this conclusion to the end of his life, even against the growing belief among his contemporaries to the contrary. We now know that his first idea was correct and that this great landmark has resulted from the impact of meteoritic matter.

In 1904 Chamberlin and Moulton advanced the planetesimal hypothesis as to the origin of the earth. But in all his geological writings Chamberlin seems to have carefully avoided identifying the present infall of meteorites with the growth of the planet. It is probable that he once hoped to demonstrate this identity. But with the facts then available regarding the rate of meteorite infall he concluded that only a layer one foot thick would accumulate in fifty billion years. This estimate was based upon the total weight and distribution of meteorites then known and the theoretical mass represented by the estimated fifteen or twenty millions of small meteors appearing in the earth's atmosphere daily. Probably, if Chamberlin had been able to accept larger estimates regarding the present infall of meteoritic matter it

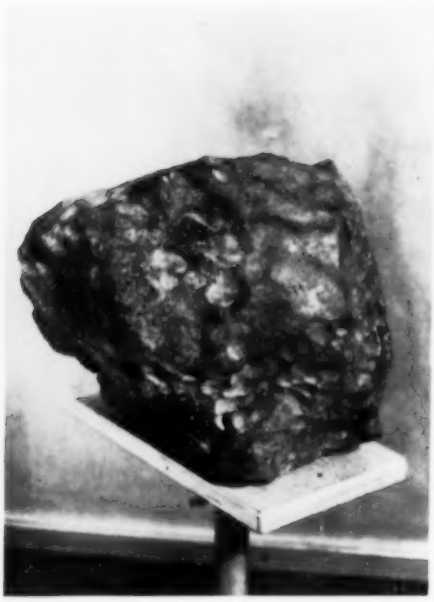
THE SITE OF THE NEWLY DISCOVERED "METEORITE-CRATE" IN KIOWA COUNTY, KANSAS. THIS "BUFFALO WALLOW" HAD BEEN FARMED OVER FOR MANY YEARS BEFORE PROFESSOR NININGER DUG FROM IT A HALF TON OF METEORITES.

would have been much to his liking. His refusal to accept higher estimates is evidence of his extreme caution as a speculating scientist.

The estimates used by Chamberlin regarding the mass represented by small meteors has been seriously questioned and the writer is one of those who believe that a study of infallen meteoritic material and of the phenomena accompanying such falls presents conclusive evidence of much larger masses involved.

When it comes to the consideration of the only other source of facts regarding the rate of meteoritic infall the writer has long cherished the belief that more complete data were obtainable. In 1923 a plan for the systematic search for meteorites was conceived by the writer and support for this idea was sought in an interview with the late Dr. Geo. P. Merrill who was eminent in the field of meteorite studies. Dr. Merrill considered the idea unsound and attempted to dissuade me from the attempt. Other sources of support were sought without success whereupon it was decided to proceed independently in the hope that the high prices then being paid for meteorites by museums and collectors might pay the cost of the venture—providing it should prove successful.

The plan was put into action on a small scale in that year as an avocation from a college professorship and has been carried on more or less intensively ever since. Success was very tardy in arriving and had it not been for two rather good finds at the first which had been largely responsible for generating the idea, the plan might have been abandoned, for during the succeeding six years no visible results came from the effort. During these six years there were times when our recurrent disappointments led to a critical re-examination of the facts on which had been based our conviction that a proper search would prove fruitful. Always we turned from such critical examinations to resume our efforts with the same confidence that, eventually, we must succeed. Finally in December, 1929, a twelve-ounce fragment of a stony meteorite arrived from the



GLADSTONE, N. MEX., STONY METEORITE WEIGHING 100 POUNDS DISCOVERED BY AN OBSERVANT FARMER WHO HAD BEEN PRIVILEGED TO EXAMINE THE NININGER LABORATORY FIELD EXHIBIT.

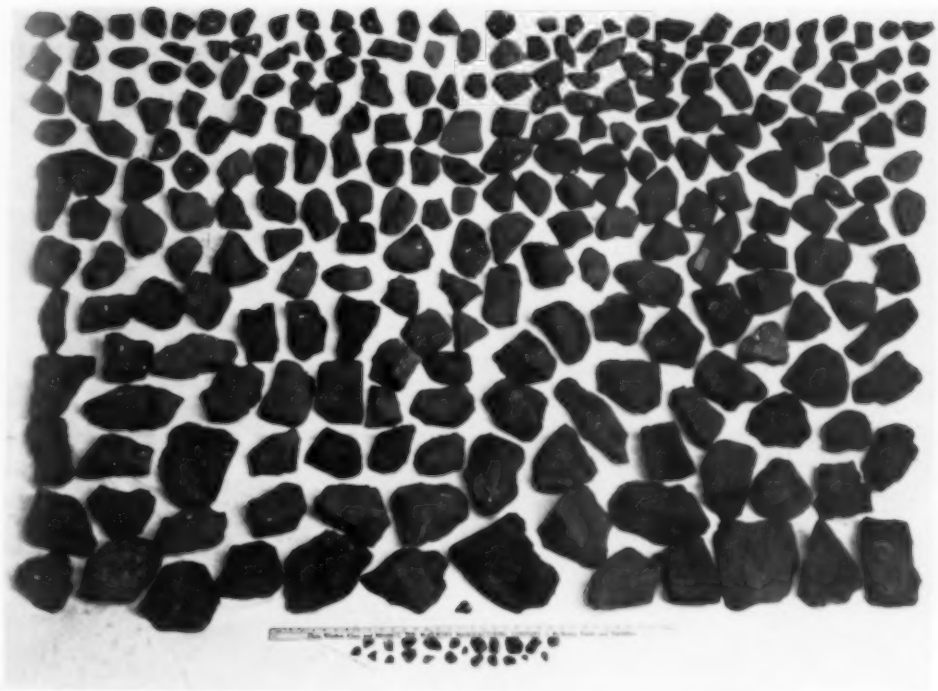
HUGOTON, KANSAS, METEORITE. THE YOUNG MAN IS J. D. LYNCH, JR., WHO, AFTER HEARING DR. NININGER LECTURE, CONCLUDED HE HAD PLOWED UP A METEORITE. AN INSPECTION CONVINCED DR. NININGER THAT HE HAD TORN OFF ONLY A CORNER OF ONE. THE 770 POUND STONE SHOWN IN THE EXCAVATION WAS FOUND BY DR. NININGER IN THE SEARCH WHICH ENSUED.

vicinity where we had worked more than four years before. The vicinity from which it had been brought was immediately visited and the ensuing search yielded more than a hundred pounds of material! Needless to say our plan was not abandoned.[1]

Our plan of search consists of a campaign among rural populations designed to acquaint the farm and ranch dwellers with the appearance and importance of meteorites. Directions are given for simple field tests to distinguish meteorites from terrestrial rocks and for specimens a price is offered as an inducement to all to keep on the lookout and report them.

The campaign is carried on mainly by means of lectures in high schools, before men's, boys' and women's clubs, through the distribution of leaflets on the Recognition of Meteorites, and by the use of local newspapers. All lectures are illustrated by specimens of the type most commonly found and warnings are given as to the kinds of terrestrial rocks, which, in the respective communities are likely to be confused with meteorites. This we call the general search. Wherever this effort results in the discovery of an unrecorded fall we subsequently conduct what is termed the intensive search. This consists of a house-to-house canvass and in some cases personal field work by a member of our staff. Even after the intensive canvass has been completed our visits to the community are frequently repeated in order to maintain the proper

[1] While this paper was in preparation a 20 pound stone arrived from this same area. All tests indicate that it is a part of the same shower as we located 10 years ago. This is an illustration of the manner in which our survey actually works.



PLAINVIEW, HALE COUNTY, TEXAS, METEORITES

THIS GROUP OF STONY METEORITES WERE COLLECTED AFTER A GREAT MUSEUM HAD SUPPOSEDLY COMPLETED THE COLLECTION OF THIS SHOWER. THEY HAD SECURED A TOTAL OF TWELVE STONES, AGGREGATING 68 POUNDS. THE NININGER LABORATORY COLLECTED 421 STONES AGGREGATING ABOUT 900 POUNDS.

interest in finding and marketing meteorites.

It is at once evident that if a search can be made successful and the yield of this celestial fruit is materially greater than had formerly been assumed, then this new information becomes of utmost importance in all considerations regarding the origin and history of our planet. By a careful study into the nature and rate of alteration undergone by meteorites in the soil a reasonable estimate may be arrived at regarding the period of infall represented by the harvest gathered. Such data would for the first time elevate our discussion of the question of earth-building above the plane of pure speculation and furnish a factual basis for a theory of planetary evolution.

Two things have strongly impressed the writer in the carrying out of this survey. 1st. *The enormous inconsistency between the amount of meteoritic matter actually collectable in a given area and the extremely small amount formerly recorded for the same area.* 2nd. *The extreme difficulty which we experience in the discovery of this material even in regions where the amount finally collected is surprisingly large.* For example, in an area where a large shower had occurred and where we collected about three hundred stones aggregating about eight hundred pounds from approximately ten square miles of level farm land, four years were required to accomplish the task after our initial discovery. What is even more impressive is the fact that this entire crop

of stones had eluded four different efforts on our part to find meteorites in that vicinity previous to the beginning of our success. Such facts suggest the probability that no search can ever be made to approach completeness. They also suggest that enormous quantities of meteorites may escape us entirely since our intensive program (so far) has been applied only where a fall has been discovered in a given region.

Early in our experience we perceived that the methods commonly employed in the collection of a discovered fall were quite inadequate and we adopted the practice of a follow-up search. Some of the results were as follows: 1st. Where two small stones, weighing together 850 grams, had supposedly constituted the entire fall we collected seventy additional stones weighing 16,000 grams. 2nd. Where twelve stones had been collected aggregating about 31 kgs. we collected 418 individuals weighing about 460 kgs. 3rd. In an area where a half dozen irons had been reported we collected forty-five additional. 4th. In the famous Brenham or Kiowa County field which yielded more than a ton of material between 1890 and 1910 we discovered a meteorite crater measuring 36′ by 55′ and from it collected about 1200 pounds of altered meteorites, besides collecting about 800 pounds of well-preserved meteorites outside the crater.

Please understand that our policy does not in any case permit our entrance into a field which has been discovered by another party until after the discoverer has "completed" his task of collecting and has abandoned the search.

Our most important work, however, is the discovery of unrecorded falls. It is here that we are constantly at work, systematically covering the Great Plains area as opportunity offers. In order to economize as much as possible we work in selected spots as guided by our discovered samples. For example, a sample arrives from Johnson county, Kansas. We forthwith go to Johnson county and if possible visit all of the schools in the county—an area of perhaps 900 sq. miles. This promotes the collection of the fall discovered, facilitates the mapping of its distribution, and also gives opportunity for new discoveries. In a number of instances we have discovered more than one fall to be present in the same county. In a few cases finds were duplicated in the same township (36 sq. miles). By reason of this "spotted" method of procedure it will be noticed that our finds are scattered over a very wide territory of some 400,000 sq. miles while as a matter of fact we have really covered by our general search something like 60,000 sq. miles of this area. Our intensive search has been applied to only a few hundred square miles.

Altogether the field program of the Nininger Laboratory (now incorporated as the American Meteorite Laboratory) has directly resulted in the discovery of eighty-four different meteorite falls. Only two were witnessed falls, both of which were surveyed and mapped by the writer preceding their discovery. Besides our direct results other workers have "taken as a cue" our plan of work and after receiving instructions in the methods employed have discovered about a dozen new meteorites during the last five years.

As may readily be imagined, the carrying out of such a program involves a great expense—some thirty to forty thousand miles of automobile travel per year, hotel and other expenses, a large volume of correspondence (chiefly concerned with reports on samples erroneously suspected of being meteorites), the printing and distribution of literature, payment for meteorites, photographs, chemical analyses, the execution of maps, etc., etc. In spite of our increasing success we still

find the discovery of meteorites a very expensive form of research, for an individual undertaking.

When compared with other lines of investigation in the fields of astronomy and geology, however, we see that the cost is small if viewed in the light of its great significance. Ours is the most fundamental of all geological problems. It definitely links together the works of the astronomer and the geologist, besides furnishing a very lively challenge to the petrographer and the mineralogist, the chemist and the physicist. Aeronautical engineers will learn much from the study of meteorites before they master the stratosphere.

Unfortunately a method of meteorite discovery was devised too late to be applied effectively in many areas of the earth's surface. We find our efforts most successful in those regions where the native sod was broken out by the generation yet living, and in regions where the soil is relatively free from terrestrial rocks and dense growths of vegetation. A reasonable density of population is desirable and the cultivation of the soil is an important factor. The lowering of the general soil level over large areas by the recent widely deplored dust storms has been responsible for several good finds and it is expected that other similar finds will be made as we have opportunity to push our search into additional territory.

Publicity in metropolitan newspapers and in popular magazines unavoidably accompanies our activities. This can not be escaped, where the nature of the work has such a popular appeal, save at the expense of developing a reputation for discourtesy. We have not found this sort of publicity effective as an aid in our search. By it the volume of our correspondence is enormously increased; but out of some 2000 samples received through this type of publicity only two meteorites have been found. The work involved such a mass of correspondence (we answer all inquiries) and in the examination of such a number of samples renders it impractical. On the other hand where we appear personally before groups and permit the personal handling of specimens the ratio of true meteorites to spurious specimens submitted is reduced to perhaps 1:25 or 1:50.

Geologists have sometimes complained that our program together with the publicity which it occasions thrusts upon them a burden of examining a multitude of useless samples. To this we reply that they are paying the penalty for their neglect of the subject of meteorites in their courses. The public—even the college-trained public have never been given an opportunity to know this most interesting subject. Hundreds of professional geologists have told me they never had seen a meteorite and not a few have actually seriously questioned their existence!

From the standpoint of pure science there is no more excuse for a man being trained as a geologist without his knowing how to recognize a meteorite than that he should be unable to recognize an ammonite as being a fossil. We can not expect all geologists to be intimately acquainted with all of the different falls of meteorites nor with all of the various species of fossils; but he should be able to distinguish a meteorite from other rocks just as he is able to know that a foraminiferous limestone is not an igneous rock. Surely no geology student should be graduated from the general course without having been privileged to examine representatives of the principal groups of meteorites in the form in which they appear in the field, and have pointed out to him their most diagnostic characteristics. When the geology of meteorites has been properly presented in geological courses the burden of examin-

MAP 1. LOCATIONS OF ALL METEORITES RECORDED WEST OF THE MISSISSIPPI RIVER PREVIOUS TO 1923.

MAP 2. LOCATIONS OF METEORITES DISCOVERED BY DR. NININGER AND HIS ASSOCIATES FROM NOVEMBER 1923 TO NOVEMBER 1937. THIRTEEN OF THESE ARE IRONS. TWO ARE STONES WHOSE FALLS WERE WITNESSED. THE REMAINING SIXTY-SIX ARE STONES OF UNWITNESSED FALL.

MAP 3. LOCATIONS OF STONY METEORITE "FINDS" (STONY METEORITES DISCOVERED, THE DATE OF WHOSE FALL IS UNKNOWN) WEST OF THE MISSISSIPPI PREVIOUS TO 1923.

ing spurious specimens will be distributed and soon the general public will have contributed many valuable discoveries.

We expect to continue our field program to a point where we shall be able to speak intelligently regarding the amount of meteoritic material in the soil of the earth. By a determination as to the approximate period of time represented by this accummulation we shall then be able to speak intelligently regarding the rate of increment of matter from space.

In the accompanying maps No. 1 shows the location of all of the falls discovered previous to the initiation of our program, a period of about sixty to eighty years of residence in the territory concerned. No. 2 shows the location of the discoveries made by our survey—mainly during the past seven years.[2]

[2] Since November, 1930, the Colorado Museum of Natural History has cooperated in this survey. Other institutions, chiefly the U. S. National Museum and Harvard University (Department of Mineralogy), have assisted by the purchase of meteorite specimens which were offered for sale. The program has also been assisted on numerous occasions by Dean M. Gillespie and O. Stanley Dresher and in one instance by W. F. Bingham, all of Denver, Colorado.

GUGLIELMO MARCONI

By Professor DUGALD C. JACKSON
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

In 1844 the telegraph of Samuel F. B. Morse, which is the type impressed on our day, was put into successful operation.

In 1866 the efforts of Cyrus Field to produce a working transoceanic cable came to fruition.

In 1876 Alexander Graham Bell exhibited his newly invented telephone.

Thus the world was gradually drawn closer together in intellectual relations by means of new physical devices. To-day we are still closer because of international radio.

Some of my learned friends assert that our intellectual intimacy gained by language transmitted in signals or directly spoken across space has increased instead of ameliorating jealousies and irritations among nations. This view, in my opinion, is not founded on adequate observations of fact. We are now in a fraction-of-a-second physical world, as far as communicating with each other is concerned. This is an encourager for friendship between nations and between individuals. The frictions now existing in the world seem to be due fundamentally to human incapacity to come promptly to conclusions that favor compromise for mutual benefit, within ethical bounds. Conclusions reached, immediate intercommunication between individuals or nations results from now available physical facilities, and processes of negotiation can be carried on more directly than formerly.

Had Sir Edward Grey two weeks earlier in 1914 been able to reach the conclusion that Britain should and would, under its treaty stipulations, protect Belgium against any warring invasion, and had he then convinced the British cabinet on that point, the powerful influence of quick dissemination of the knowledge would have been, doubtless, an important preventive influence against the World War. The facilities for communication in a fraction-of-a-second physical world were available, but human adaptation lagged. Human adaptation however does become gradually more versatile and we come more and more to use quick communication with more friendly results. This gives hope for betterment among nations.

Responsibility for this fraction-of-a-second communication over the globe in the spoken word, stems romantically from the efforts of one man. Let us see how it came about!

On April 25, 1874, an Italian boy-baby was born in Bologna to the name of Marconi. He was the third son of his father. At his conception there must have occurred an extraordinary combination of chromosomes, for he was born a notable mutant of mental qualities and ambitions not obvious in his well-to-do and competent ancestors and brothers. His mind, beginning with early maturity, never ceased searching the infinitude of the unknown in nature; and his grasping of relationships enabled him to originate wireless electric communication and push it forward to extraordinary scope. He died in Rome on July 20, 1937, belonging in the temple of fame alongside of Alexander Graham Bell, Thomas Edison, Frank Sprague, George Westinghouse, Elihu Thomson and others, each of whom was parent of some great employment-giving and labor-saving industry in the field of electrical engineering. Bell and Thomson were foreign born, but turned American. Marconi never relinquished his fatherland, but he found in America an early assured and wide recognition.

Successful research men who are interested primarily in identifying additional phenomena of nature, or in discovering the relationships of such phenomena, are

very eager to peer into nature's guarded enclosures. Usually they are not ambitious for spectacular acclaim or for big money; but, being human, they are charmed by reasonable recognition. To such men, the problems and routine of patenting, and the restraints of secrecy in carrying on investigations, are distasteful. Utility for their results delights many such, but to feel under obligation to mould the results into that utility tends to appal and disconcert them. Such men should be supported by endowments. They belong in educational institutions, and endowed institutions for research, because they usually delight in the contact with young and fresh minds.

Add another taste or desire to the just spoken-of instinct for peering into nature's guarded preserves—the desire to make each discovery of immediate extensive utility to mankind—and the great discoverer-inventor is produced. When born to the world he must have in him the origins of discriminating mathematical (*i.e.*, analytical) powers which will aid him to conduct explorations, imagination for arousing a vision of a promised land, curiosity for inciting experimentation, penetrating powers for observing results of analysis or experiments, synthetic intelligence and enthusiasm which guide invention. Such a man was the Marconi who was born in 1874. We will now examine the phenomena of his productive life, beginning with its background.

Hans Christian Oersted, professor in the University of Copenhagen, announced to the world in 1820 his experimental proof that an electric current coursing in a conducting wire disturbed a magnetic compass-needle standing in the neighborhood of the wire. This information spread to the intellectual centers of the world as rapidly as the then state of transportation and communication of intelligence permitted. The year 1820 was on the eve of the development of steam railroads, the electric-telegraph was still unborn, and intelligence was transmitted by couriers or by horse-drawn coaches. The announcement from Oersted created lively interest wherever received. The results of its stimulation on the minds of Ampere and Arago in Paris are well known. I have seen it stated that, years later, Michael Faraday in London said of the Oersted discovery, "It burst open the flood gates of a domain in science, dark till then, and filled it with a flood of light."

Immediately upon the publication in London of Oersted's discovery, Humphrey Davy, professor in the Royal Institution, took a copy of the paper to the laboratory and he and Faraday (then an associate of Davy) went over the experimental work. Faraday's mind was inflamed, and in 1821 he produced continuous motion from the reactions between an electric current and a magnet. Subsequently, he made the cardinal discovery of the relations called electromagnetic induction, and he espoused the concept of fields of force and lines of force. His epochal work was accomplished while he was Fullerian professor in the Royal Institution.

Later on, this very work of Faraday stimulated James Clerk Maxwell to reflection and ultimately, when professor of experimental physics in the University of Cambridge (England), he published an epoch-making treatise on electricity and magnetism which contained extended mathematical discussions of electromagnetic waves. Maxwell became a professor in a Scotch college when twenty-five years of age. He entered his professorship in the University of Cambridge at forty. His theory of electromagnetic waves aroused ardent discussion and considerable controversy, especially as it involved the phenomena of light, but no one immediately undertook to determine its validity by the pragmatic test of experiment. Indeed Maxwell died (at 48 years of age) before the validity of his theory was demonstrated by the experimental work of another college professor.

Heinrich Hertz, professor in the Carls-

ruhe Polytechnicum in Germany (later at Bonn University), was the man who made that demonstration. It was accomplished in the latter part of the decade of the eighties and its publication deeply stirred the scientific world. By that period, railroads, steamships, electric-telegraphs, all contributed to rapid dissemination of important information, and both scientists and amateurs in Europe and America began a mad scramble of experimentation with the interesting phenomena that Hertz's work had opened to observation. Among these investigators were distinguished professors of physics like Righi of Bologna, Branly of Paris, Slaby of Berlin, Lodge and Crookes of England. Talk arose of electromagnetic waves becoming the instruments for the transmission of intelligence through space, but none had achieved as yet the genius and courage as an inventor which were required to bring such a conception to embodiment.

The field had been leveled, ploughed and cultivated and lay awaiting the advent of a planter (an inspired inventor) who could plant the seed and harvest the crop for the benefit of mankind, by adapting these electromagnetic waves to the wireless transmission of human intelligence over long and short distances. This inspired genius was the already referred to Marconi boy (Guglielmo), born in Bologna, Italy, in 1874, the youngest of three sons of a father of some wealth. His mother, a second wife, was musically minded and Irish, of the Jameson family, of whiskey distilling fame. Bologna in 1874 was nearly ready to celebrate the centenary of the theory regarding electric reactions propounded by Luigi Galvani, the first of the great contributors to electrical knowledge hailing from that city and the two-hundredth anniversary of whose birth has now been recently celebrated by the city and university.

The boy Marconi seems to have been delicate and without interest in hard physical play, but he loved reading and was a devotee of fishing, horseback riding and sea travel. His schooling was principally by tutors and his own reading and experiments. A biographer tells of his interest in the letters of Benjamin Franklin regarding experiments with electricity, and how he reproduced Franklin's plan of causing a bell to ring at times of thunderstorms by the effect of electricity drawn through a lightning rod. He was still at the moderate age of twenty when his attention became attracted by the phenomena which directed the passion of his life.

Heinrich Hertz (the already referred to German college professor) died on January 1, 1894, seventy-five years after Oersted in Copenhagen was, philosopher-like, turning over in his mind the problem of relations between electricity and magnetism. As is usual in obituaries of men of note, those published upon Hertz's death summed up the influence of his work and, in some instances, described his experimental investigations at considerable length. A journal containing such an obituary fell into the hands of young Marconi while he vacationed in the mountains in 1894. This was the stroke required to detonate the passion of genius. Marconi later described his impressions thus: "It seemed to me that if the radiation could be increased, developed and controlled, it would be possible to signal across space for considerable distances. My chief trouble was that the idea was so elementary, so simple in logic, that it seemed difficult to believe no one else had thought of putting it into practice. . . . From the first, the idea was so real to me that I did not realize that to others the theory might appear quite fantastic." Others had, indeed, thought of the application, but none had had the call of invention required to find the way to the embodiment.

It is the part of genius to bridge by invention an apparently impassable gulf. But when the bridge is established and the gulf has been crossed, an achievement

that previously, as an hypothesis, appeared to be beyond the limit of human powers, now (in its embodiment) seems very simple. That is a characteristic of many great inventions. At any rate, Marconi's genius was now on fire and he reflected, sketched and planned during the rest of the vacation so that he could enter upon actual tests immediately upon returning to his father's estate. He was a few months past his twentieth birthday.

His first trials of his idea were failures, like Faraday's first trials of his ideas regarding the relations of electromagnetic induction; but soon he was able to transmit signals short distances. He proved to his father that this result was actually the outcome of his project and became the happy recipient of 5,000 lire, given to encourage his activity. (In those days the lira was worth about twenty American cents.) He was using an induction-coil with spark gap for an oscillator-transmitter and a resonating gap for receiver, following Hertz and Righi; but the results were disappointing. Something more was needed! Signals could be transmitted, but only over short distances.

This was still a laboratory matter in the spring of 1895. Others had already achieved perhaps as much, but that was in the course of ordinary lecture-room experimenting and Marconi had his ambition set on the space-transmission of intelligence from man to man.

Marconi's solution was startling. It arose from inspired thought. He electrically connected one terminal of his oscillator-transmitter to the ground and the other terminal to a bit of conductor at the top of a pole. He introduced into his receiving circuit a device called a Branly coherer, and here also one terminal was connected to ground and the other ran to the top of a pole. In these pole-supported conductors were the first embodiments of the elaborate antenna structures with which we are now all familiar, at least as an object on the landscape even if not as a part of our technical acquaintance.

With this arrangement he gained distance of transmission in spite of the crudeness of his apparatus. The sending and receiving antennas, associated with grounded circuits, had achieved his end. Wireless telegraphy was a fact. Innumerable refinements have since been introduced but, in all instances, Marconi's fundamental embodiment remains. Tuning of circuits, choice of frequency, new transmitters and receivers, directional antennas, substitution of speech for telegraph signals, broadcasting, all are refinements, improvements, or extensions, but all hang as embellishments on the original gem. All who have practiced invention know well that at that time the mental exaltation of Marconi must have been high. Marconi is one of those who learned early that the long road of invention is rough but that it provides some glorious vistas.

The announcement of his results, made in 1896, created great excitement among the physicists of the world, who began an ardent discussion of the mechanism of the waves, their emission and capture by the sending and receiving antennas, their velocity of propagation (was it indeed the same as the velocity of light?), how penetrative were they, could they follow around the curvature of the earth, and many other factors. There also arose a flood of mathematical and experimental investigations in this field of phenomena, the doors to which were so unexpectedly thrown open.

It is said that the Italian government took no interest in this project of its youthful citizen, when Marconi called it to attention in 1896. Therefore he went to England, where he took out a patent covering his fundamental embodiment—the first patent ever taken out for wireless telegraphy specifically described as based on electric waves. He was welcomed in England and given hearty cooperation in extending his demonstra-

tion. Then, in July, 1897, a company was incorporated to support his investigations and to enter the field of commercial wireless telegraphy. At that date a transmission distance of about ten miles had been achieved. This company secured Marconi's rights to wireless telegraph inventions throughout the world, except in Italy. The latter Marconi held out for the benefit of his fatherland.

There followed, in England, many years of great activity. Stations were set up for communicating with lighthouses and with ships at sea. Exacting research was also carried on. During this period Marconi invented the application of tuned circuits to wireless transmission and reception, thereby improving the effectiveness and selectiveness of wireless telegraphy, and also enabling, if desired, a multiple of messages to be simultaneously transmitted or received on an antenna. This has a bearing on wireless telegraphy and telephony of importance almost equal to the primary invention patented in 1897. In these early days he also visualized radio processes of transmitting direction-bearings to ships; and he was constantly on watch for hitherto unobserved and unexpected phenomena and was occupied in inventing improvements. He by now had gathered around him a group of notably competent aids who also were active in devising improvements. Distance of transmission was steadily increased. "Marconi wireless" became the talk of two continents.

About this time an American reporter said of Marconi: "He is a mere boy, with a boy's happy temperament and enthusiasm, and a man's nervous view of his life work. His manner is a little nervous and his eyes a bit dreamy. He acts with the modesty of a man who merely shrugs his shoulders when accused of discovering a new continent."

There was drama in all this development. Flinging readable signals into space, to be picked up perhaps a hundred, perhaps two hundred, miles away was itself dramatic as a realized entity, although not difficult to conceive as a dream-effect. But now this drama began in good earnest. Ships in trouble began to call for help by their installed wireless apparatus; and others, in response, to rush to give aid. Then came that exhibition of confidence and courage at its height which is allowed in the life experiences of but few men, and occurs but once (because of its transcendent character) in the life of any man. For Marconi this was the dispatch of readable signals from the southwestern portion of England to St. Johns, Newfoundland, two thousand miles away—the letter S, three dots in Morse telegraph code, repeated according to a predetermined manner. Some were skeptical when this achievement was reported; but the scientific world was thrilled, although it then (December, 1901) did not know how the electric waves could follow the curvature of the earth and some had denied the possibility.

Marconi's achievements already had raised him to a level of high respect for his ability and his sterling reliability. The New York *Times* commented on the feat of transatlantic signalling in a manner that is worthy of repeating:

> It can not have escaped notice of those for whom the subject of wireless telegraphy has even a news interest, that to establish the fact that the feat had succeeded of transmitting intelligible signals in prearranged order and frequency of occurrence no other evidence was needed than Signor Marconi's unsupported and unverified statement. Immediately on receipt of telegraphic intelligence from Newfoundland that this feat had been accomplished representative engineers of the world were interviewed, and without exception their response was: "If Marconi says it is true, I believe it!" . . . No higher tribute could have been paid by the world of science to an inventor than was paid Marconi by this unquestioning acceptance of the announcement that he had succeeded in accomplishing the seemingly impossible.

A few months later Marconi, on the steamship Philadelphia, while crossing the Atlantic Ocean from Europe to

America, received signals and messages over a still greater distance; and the time had come to establish plant for commercial service between these two continents. It was on this trip that Marconi also made the important observation of a difference between night and day in the strength of signal transmission. Now the world did indeed take notice, and honors flowed in to Marconi. In mid-1902 the Czar of Russia met Marconi when he entered a Russian harbor during some of his observations, and on leaving him said, "I am assured your invention has tremendous possibilities. It should prove a blessing to all."

The drama now turned to averting or ameliorating tragedy. Various rescues of small groups of people from shipwreck had been made on call by wireless. Then impressively great achievements brought the life-saving possibilities of radio spectacularly into the public consciousness. In 1909, 461 people on board the sinking steamship *Republic* were taken off in safety by the steamship *Baltic,* called to the rescue by radio, while other ships similarly brought to the scene stood by. This was near the harbor of New York City and various large ships were within easy distance.

In 1912 the disaster to the steamship *Titanic* occurred, and the far-away *Carpathia,* called by radio, rescued 712 lives. Some or all of the 1,517 who were lost would have been saved, it was thought, if all vessels in the neighborhood at that time had been suitably equipped with the wireless apparatus. In 1913 the people who stayed with the ship, to a total of 521, were saved from the flaming *Volturno* by ships called to the rescue by radio. In this instance the difficulties of rescue in stormy seas were lessened by means of oil on the water from an oil-carrying ship called to the spot by radio.

By this time, travellers and shipping people became convinced that all steamships ought to be provided with wireless telegraph equipment and that great passenger ships should carry two or even three operators, so that safety supervision could be always available. The first wireless shipping report had been published by Lloyds in 1910, the importance of wireless to the mercantile marine having then already become recognized, but this was ship-to-shore business and the rescue problems were now proved to be largely ship-to-ship communication problems.

At 5 A.M. on November 11, 1918, went forth from the Eiffel-Tower radio-station in Paris one of the most pregnant and dramatic announcements ever carried by electric waves. It came from the authorship of Marshall Foch and announced the end of military hostilities in the world war. It read: "Marshall Foch to the allied commanders: Hostilities will cease at 11 A.M." This word of the cessation of hostilities is said to have reached by wireless one half of the allied troops who then numbered several million men. Marconi is reputed to have said in later years, "I prefer to think of the lives that have been saved by wireless, rather than the uses to which it might be put in wartime."

We now, in our present year, have before us the convenience of radio (*i.e.*, wireless) communication in a flash of time, by telegraph and by telephone, into all parts of the world where there is a need for it. Radio has expanded into various other branches which are aside from the original objective that stimulated Marconi's mind. The radio has become a commonplace of life through the results of steady expansion and improvement. Such a tremendous industry founded on one man's inventions, and affected by the researches and inventions of rivals following him into the field, arouses many disputes regarding the fundamental priority of the inventions and the patents describing them. Marconi's work was no exception, and his great fundamental patents were warmly contested. As the development of radio unfolded, the early awe-inspiring wonder

among the people disappeared, and the whole enterprise became a simple public affair. Marconi said some half-dozen years ago: "I think I may say that the people will cease to wonder at wireless. The only wonder will be that there was ever a time when it was unknown."

When we contemplate the magnitude of influence inherent in radio as we know it, which is truly the blossoming from Marconi's pioneer work, we can feel gratified that Marconi's fundamental patents have been generally sustained. The attitude of American courts is indicated in the following paragraph from a decision of 1905.

> It would seem, therefore, to be a sufficient answer to the attempts to belittle Marconi's great invention that, with the whole scientific world awakened by the disclosures of Hertz in 1887 to the new and undeveloped possibilities of electric waves, nine years elapsed without a single practical or commercially successful result, and that Marconi was the first to describe and the first to achieve the transmission of definite and intelligible signals by means of the Hertzian waves.

In the foregoing I have said little of the man and his personal life outside of his great work of invention and development. This is appropriate, for that great work absorbed him and was his life in a large sense. Nevertheless he was twice married. Once, the end was unhappiness and divorce. The other marriage seems to have turned out adorably. Three children from the first marriage, I know little of. The child of the second marriage, a daughter now nearly eight years old, is reputed to be a very charming little girl.

Upon his death, Marconi possessed decorations of high order from many nations; academic honors from many universities; and many famous medals and prizes, headed by the Nobel Prize for Physics conferred on him in 1909. He was Senator of the Italian Kingdom and hereditary Marquis by creation of His Majesty the King of Italy. In January, 1928, he was appointed President of the Italian National Council of Research; in November, 1930, he became President of the Italian Royal Academy and Member of the Council of the Fascist Party; and in February, 1931, he was appointed by His Holiness the Pope a member of the Pontifical Academy of Sciences. The friendship of the King and Queen of Italy and of the Duce during many years, with which was associated the helpful cooperation of all government authorities, eradicated any unhappiness that Marconi may have had originally on account of the coldness of his government toward his project in its youth, and his funeral was an official affair of great dignity accompanied by a spontaneous outburst of respect and mourning by the Italian people.

Marconi's productive qualities as an inventor arose from a nature illustrated by a comment from him which is reported by one of his biographers:[1] "I'll tell you, if you set your heart and soul in a thing, you can do it." The aid which he derived from originating in a well-to-do family is illustrated by his comment when asked what he would have done had he been poor. He said, jocularly perhaps, "I don't believe I would have been an inventor. I might have been a sailor." He loved the sea, but the inventive spirit burned strong within him and it is not safe to assert that he would not have been an inventor in some degree, even if he had been a poor sailor following the sea.

It takes a genius to write a *good* short story in the literature of any language. Many short stories start well and others have good endings. Those are written by individual authors of ordinary merit; but one who is a genius can write a short story that is satisfying in both start and finish. It often is different with fundamental inventions in the scientific world. One genius is not enough for such. It usually is necessary to expend (in sequence) the efforts of one or more investigators on discovering the needed funda-

[1] Orrin E. Dunlap in "Marconi, the Man and His Wireless," published by The Macmillan Company.

mental facts in nature's gallery, and of an additional individual (the inventor) to complete the chain and mould the applications of those facts to the use of man. In the example of wireless communications (or radio, as we now call it), the principal sequence comprised four matchless men—Michael Faraday, James Clerk Maxwell, Heinrich Hertz, Guglielmo Marconi. Although we usually give first place to Faraday, it is truly difficult to say which was the greatest of these men, for each contributed largely to the comfort and convenience of men and to knowledge from which farther convenience can be distilled as inventors seize the opportunities. It is more reasonable to ascribe first place jointly to Faraday and Maxwell because their investigations and discoveries were so fundamental that various great applications have stemmed out of their work and others may yet do so. Nevertheless, Marconi's work uncovered so many previously unnoted phenomena that we are not yet able to put a limit to the ultimate outcome. Faraday said of himself "In early life I was a very lively, imaginative person, who could believe in the 'Arabian Nights' as easily as the 'Encyclopedia,' but facts were important to me and saved me. I could trust a fact." And again, "Without experiment I am nothing" and "But still try, for who knows what is possible." Also, "Let us encourage ourselves by a little more imagination prior to experiment." These phrases could be equally applied to Marconi's qualities, but Faraday's mind was directed to identifying fundamental phenomena and their relationships, while Marconi's was set on producing useful applications.

There is a moral in the sequence above named, which holds interest for those who wish to advance human comfort and convenience, and I can not refrain from expressing this moral to you. Faraday, besides many other great achievements, thought out and experimentally demonstrated the phenomena of electromagnetic induction and also outlined the conceptions of fields of force and lines of force; Maxwell thereafter synthesized such ideas by means of powerful mathematical treatment, thereby premonstrating the existence of electromagnetic waves in space. Hertz experimentally proved the truth of Maxwell's predictions regarding electric waves, and provided means for producing and for detecting electromagnetic waves of a range of wavelengths. The way was then open for the inventor, Marconi, to carry forward, and wireless communication of intelligence sprang into being as the child of his labors.

Such is the character of sequences through which nowadays arise the great inventions from which influential industries spring. The age of the individual inventor struggling in scientific darkness to bring forth a great invention, as Watt did for the steam engine, Fulton did for the steamboat and Goodyear for the vulcanization of rubber, is in its waning period, if it is not already gone altogether. The day of sequential scientific discovery, followed by invention which completes the chain and produces results out of which important industries spring, is with us. Even Watt, Fulton and Goodyear worked from platforms of vague knowledge established by sequences of their predecessors.

We are now applying to man's purposes the more refined and abstruse features of nature's phenomena. This presses a strong emphasis on the importance of scientific research of fundamental character if we wish to have continued the progress of invention that contributes new industries for our advantage. Support for such research of fundamental character into nature's phenomena, provided in the way of endowments and government appropriations, is an important basic factor in raising to higher levels man's comfort and convenience, and in improving the mutuality of interests between men. I commend this idea to your reflective minds as a primary principle which is emphasized out of the work of such inventor-geniuses as Marconi.

SCIENTISTS SOMETIMES TELL THE TRUTH

By the late Dr. MAURICE C. HALL[1]

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ONE of Mark Twain's maxims is to the effect that truth is the most precious thing we have, and, therefore, we should economize it. The statement is a blend of fact and of the cynicism characteristic of Mark Twain and other judicious persons who, on critical inspection, find the world, and more especially the behavior of people, something less than satisfactory. It is an appreciation of the fact that, in a society that speaks very highly of truth, personal indulgence in truth telling is a mischancy and hazardous occupation for thoughtful individuals. In this respect, the present time is probably no worse than former times, and may be somewhat better. In all ages it has been customary to stone the prophets, to ostracize any Aristides the Just that might arise, to compel the recantation of Galileos or burn them at the stake, to imprison innovators, to deride Fultons and Langleys, and to lop off the heads of such heretics and freethinkers as do not concur in the dicta of the current magnificos of State, church and similar collective organizations. The precise forms change, but the basic reactions are identical, and, for this or that reason, we are economical of truth.

Yet the present time differs a bit from former times in that we now have a very large group of persons devoting themselves to ascertaining the truth by somewhat precise and critical procedures in lieu of seeking it by revelation, introspection or the ratiocination of logic without benefit of observation or experimentation. These persons call themselves scientists. As students of science these scientists receive a certain amount of attention, but as subjects of scientific research the group has had too little attention. A few persons, such as Ramón y Cajal, have given them passing consideration, as I do here, but what a scientist would regard as a critical study of the group has never been made. It is pointed out here as a good subject for research.

Quite visibly, scientists actually seek for truth in their occupation as scientists. Equally visibly, scientists do not seek for truth to any notable extent outside of their occupation as scientists, when acting in their capacity as human beings. As human beings they are constrained by the same internal and external inhibitions that operate on all human beings. Internally they are shaped by the same forces that establish all childhood patterns of behavior. They have the same incapacity for examining their patterns by the critical methods of science, for justifying their behavior by the demand for adequate evidence, and for sustaining their childish beliefs by the demand for sound reasoning. Anthropologists and ethnologists have traced the roots of most of our childhood behavior and beliefs to primitive sources, but scientists in general are content to regard those findings as applying to other human beings, and to ignore the possibility and probability that they themselves are behaving in the customary affairs of life, outside of their laboratories, precisely on a par with Eskimos, Fiji Islanders, Toltecs and cavemen. Economists and sociologists have clarified some aspects of problems of production, distribution, crime and maladjustment, but scientists in general discuss these subjects with the same light touch that has characterized their ancestors back through untold generations. It is obvious that they inherit their religion, politics, morals and manners, and follow them as

[1] Died May 1, 1938.

deviously and uncritically as did the men and women of ancient Tyre, Gomorrah or Carthage.

The reason for all this faulty behavior is sufficiently obvious. We have nothing better than human beings from which to make scientists, and such material is clearly defective. As human beings, we have our thinking complicated by our emotions, and limited by our childhood beliefs. These things are forces that push us from the straight path of reason, or even stand astride the path and hold us back. The result is, in some ways, pathetic. Our work as scientists lacks the sparkle of originality and individual thinking because we are set and molded in youthful habits of thought. We follow patterns taught us, and slip into grooves from which we extricate ourselves with difficulty, if at all. To a great extent, our research follows some blueprint as evidently as does that of a carpenter or mechanic, and often shows as little, or even less, evidence of art or craftsmanship.

When we scientists have arrived at some morsel of truth, we display, somewhat too often, a bit of disregard for truth and precise honesty in the presentation of our findings. Too often, a joint paper presents the work done by the junior author, without the saving grace of a statement to that effect. Rationalizations which are not quite sound and scientific are alleged as arguments justifying papers that should fly the Jolly Roger of piracy. Directors of research, from project leaders up to the Herr Doktor Direktor, are in special danger of playing the rôle of Captain Kidd, and some few degenerate into intellectual parasites incapable of taking two borrowed or stolen ideas and deriving from them a third idea of their own.

In the course of 30 years, I have observed various experiences bearing on this matter of truth and honesty in scientific publication. On one occasion, a writer lifted about four pages from another man's papers, and incorporated it in his paper without benefit of quotation marks, credit or bibliographic citation. While the original author appreciated the compliment, and certainly was not harmed by the procedure, the borrower's action was hardly in line with the nicest considerations of honesty and courtesy. While in the field on one occasion, a scientist pointed out to a younger scientist two species of animals of which he stated that one would probably be the intermediate host of a certain parasite with a then unknown life history. One of the younger man's associates undertook the problem in life history, and found that one of these species was the intermediate host. The report of the work gratefully acknowledged assistance from many persons, and the omission of the older scientist's name was probably because government scientists are supposed to be paid for such work, and have no amateur status entitling them to compete for such trophies as acknowledgments. One writer has blithely chucked a brick at another in print, in connection with a subject with which the latter had no direct connection whatever, and only a very remote and devious historical relationship, the brick, apparently, being heaved purely in a spirit of good, clean fun. As age comes on, it becomes increasingly interesting to note that ideas set forth by one scientist many years ago are commonly charged to writers of 3 or 4 years ago, who, naturally, are not citing authority for accepted ideas, a form of carelessness unworthy of scientists. The 1936 report of a highly important and useful organization contains a statement in regard to recent research on anthelmintics, and concludes by saying: "From these anthelmintic studies it appears that there is now available for uncomplicated hookworm disease a safe and effective drug in tetrachlorethylene." It is gratifying to report that these 1936 findings were confirmed over a decade earlier by the two scientists who proposed the drug

in 1925 as an effective remedy for hookworm infestation, and have been confirmed by a decade's extensive experience in human and veterinary medicine as a safe remedy. Concerning these things, one need have no emotional reactions. It is not necessary to write letters to the authors or the editors, since the printed records stand available to all critical scientists who seek for facts in the literature and history of science, as well as in their laboratories, but they are mentioned here as the evidence from writers, who are here kept anonymous, as to the fine disregard for truth and fact that characterizes too many scientists on too many occasions. This disregard, as it appears in the performance of persons engaged in the pursuit of truth, is something of a disappointment.

On the other hand, and most curiously, a sentence from one of my papers was referred to by a writer, within five years after its publication, as "an American saying." When I read this, I feared for a moment that I was on the way to become a legendary figure or a solar myth.

If our performance in science is not quite in keeping with our high status as seekers after truth, it is hardly to be expected that we will make a much better showing in our performance as individuals. The motto of legendary Poictesme, *Mundus vult decipi,* is not fantastic—the world does wish to be deceived. This world that desires and admires deception, sleight-of-hand, magic and miracles is no safe place for truth or persons who are unrestrained in the telling of truth. It is a world in which those who wish the crown of martyrdom may find it, but the scientist has his work to do, and commonly manifests no eagerness to shorten the little span of life in which he may gratify his curiosity about this and that tiny segment of an extremely interesting and thought-provocative universe.

If the findings of scientists who range among the stars, or through the buried strata of the earth, or into the chromosomes, do not in all respects confirm the thoughts of the prophets, law givers and persons in high places, it is convenient, and possibly advisable, to confine our findings and our derived opinions to selected colleagues, or hint at them, as I do here, in such glittering generalities as convey nothing specific that might give offense to someone's cherished childhood beliefs.

Such behavior on the part of the scientist is in keeping with the basic and not too admirable habits of the human animal. For externally, as well as internally, the scientist is inhibited and restrained. Life is still a struggle for existence; and physical, economic and social suicide are alike distasteful to normal human beings. Life is short, and the scientist's art not merely long, but endless. While thousands tramp the streets in search for work and sleep in "flophouses," the scientist will feel no eagerness to join them as evidence of his distaste for a society in which reward bears no visible relationship to merit. If society displays a hypocritical attitude in paying lip service to virtues which it does not practice, the scientist will invite no display of intolerance by specific public criticism, even though he fail to pay compliments. He will continue to follow in his laboratory the methodology of controlled experimentation, careful observation and sound reasoning, so far as he is capable of such difficult business, and, if he is optimistic, he will trust that the human race will some day apply the same methodology to the matter of government, religion, society, business and similar collective enterprises.

For the individual must adjust to society, and that adjustment can be a quite happy one only in a non-existent society of intelligent and social-minded individuals. To-day's emphasis in teaching is increasingly on the development of individual thinking, and psychology is emphatic as to the evils of mob psychol-

ogy and mass thinking. Yet this teaching is precisely the road to maladjustment to society in a world in which no man and no woman may live in anything closely approximating honesty other than by an outward and apparently whole-hearted acceptance of the mores of the mob's 14-year-old intellects.

Until society applies the methods of science to our community life, the living of all thoughtful persons will be warped and deviated. Surely, thoughtful persons can not and do not conform their living to modes readily detectable as vestigial remnants of the mores, taboos and tribal customs of neolithic man. Thoughtful persons can not subscribe to ideas contemporary, and on an intellectual par, with those of troglodytes who lived in a flat world infested with the prehistoric equivalent of gnomes, elves, werewolves and other demons who were kept at bay only by the use of appropriate charms, rituals and ceremonies, or the occasional sacrifice of such individuals as the medicine man might select. It is enough that the long-departed dead lay their hands on us through heredity, mixing in us desirable and undesirable things, and by the element of chance confirming a biological doctrine of predestination. It is too much that these dead of long ago should still determine all our living, and that we should not settle today's problems for ourselves as they settled them for themselves. But in the doing of this, thoughtful persons shape their living to such outward conformity, such private evasions, and such inward adjustments as may meet the demands of the moronic herd and still allow some measure of personal and individual life. Such a life is a blending of outwardly honest and inwardly false living with outwardly false and inwardly honest living. It is an unsatisfactory and unhappy compromise between an individual that seeks for truth and a society that prefers falsehood. It is, in fine, the same mode of life as that of all crooks, villains, hypocrites, and social offenders of high and low degree, and so may be put down in the customary set terms as a failure of adjustment to society.

As usual, our set terms are a bit too inflexible, a bit misleading. As a pattern followed alike by good and bad, intelligent and mentally defective, one may conclude from such a mode of life that, although a primitive savage may happily obey his tribal taboos, civilized society is so constituted that honest adjustment to its pattern is possible to no human being whatsoever. This is probably true, and may, to some extent, account for the enthusiasm with which mankind welcomes the dictator who promises miracles, and proposes to pull from his hat or sleeve, after the fashion with which prestidigitators produce white rabbits, a social organization molded more closely to the heart's desire of all. The scientist, who has lost his childhood belief in fairy godmothers, will feel little stir of surprise when the Promised Land of the dictator turns out to be a land in which all are molded to the pattern of the dictator, and no other person may call his soul his own. Yet the scientist will continue to hope for a society in which one may live honestly and speak the truth somewhat oftener than sometimes.

In the individual life of the scientist, he likes to think that reason sits at the wheel and steers his car. It is, unhappily, only a conditioned thinking that makes him believe this. For the car is full of back-seat drivers. The emotions, good and bad, insist on this road; the endocrine glands on that; magic compels this stop; pretense compels that start; and, in the end, compromise settles most of the arguments between the driver and the back seat. And compromise is the foe of truth and honesty. So we live falsely and compromisingly, and in defiance of the categorical imperatives of science. Nevertheless, some of us live thus only reluctantly, and it is depressing to note that philosophers, metaphysicians

and even some scientists in high places, under visible pressure, openly set such a value on reason and such on the back-seat drivers as lead to the conclusion that it is a high philosophy to let one of the back-seat drivers take the wheel. Emotions which to our minds are not laudable are given preference—hates and phobias and childish pride in this or that unreal thing. In sum, the "amor fati" of Nietsche, an acceptance of life, nay, a rejoicing in life, as capable of no improvement except as a blind fate directs it, is set above reason. In the interplay of choice and chance, chance is elected ruler. It is a rejection of the brain as a reasoning instrument and as a determinant in the destiny of mankind, and is a selection of automatism, as determined by adrenal glands and such lower organs, as better than conscious intellectual effort. Yet the scientist may question whether reason can be thrown out of the car, and whether there will be any gain or any less conflict from putting reason in as a back-seat driver. For this restless mind is as indestructible and as active as the emotions, and it, too, if it can not steer, will grab the wheel from the driver on occasion, and resume it as soon as possible.

It is the fashion of some militarists, dictators and philosophers to laud the dangerous life, lived in the expectancy and realization of war, as a sharpener of wits and a developer of courage. The scientists may look with some contempt on this philosophy. If we wish to fight, we need no wars, international or civil, to provide fights. Nature still fights us with her weapons of heat, cold, famine, disease and death, and in the war against Nature in the defense of mankind there is ample score for the qualities of sharp wits and courage. The conquest of disease affords ample opportunity for daring, suffering and death on the part of the scientist. It calls for a quality of calm, intellectual, individual courage that is far superior to the emotional mass courage of men disciplined to unquestioning obedience to orders. The war on disease has developed mental alertness far more evidently than has warfare of man against man, and intelligent persons in general evidently prefer science to military life. In the long lists of warriors in man's thousands of years of war, the really able generals can be counted on the fingers of both hands; a mastery of military strategy has been one of the rarest of accomplishments; and the tale of the world's battlefields is mostly a monotonous history of two opposing generals making mistakes until one makes a fatal mistake and the other wins by virtue of his opponent's greater stupidity. With all the flaws of scientists who can not measure up to a strict bill of specifications, the short history of science can present a long list of able men as competent in science as was Napoleon in war; scientists in general use strategy and tactics of a much more complicated sort than those of the military men, against enemies that moved by land, water, air and subterranean channels long before man had mastered anything but land movement; they master their strategy and tactics so well that they quite generally win the innumerable campaigns in which science engages; and the battle flags of science rarely bear the name of a battle-field from which science has gone away other than as a conqueror. The battles we have not won are mostly the battles we are still fighting.

Psychologists and sociologists tell us that man goes to war because his peace-time life bores him, it lacks the romance and adventure that he craves, it imposes responsibilities without compensatory rewards, and even to the minds of uncritical persons it is definitely not the thing which childhood pictured, which art and fiction paint, and which the heart and instincts desire. The blood of ancestral cavemen, soldiers and adventurers rebels at an overcomplicated and formal living in regimented modes. So thoughtful persons who love peace advise us to find an

attractive substitute for war if we wish to abolish war. The scientist has such a substitute. He has intellectual interests beyond those of generals, and he has the hazards of injury, disease and death from his work with radium, x-rays, explosives, poisons, bacteria, viruses and parasites. The scientist, engineer and explorer, the worker with hot steel and high-speed machinery, and all the company of those that fly the air, bore under rivers, fell great trees, and blast away cliffs—these need no war to make life adventurous.

But it is not solely the fact that the scientist's life has in it elements of romance, adventure and danger that makes it a substitute for the soldier's life. It has in it, intrinsically, those elements of truth and honesty which we need to make possible a satisfactory adjustment to life. Our peace-time life has in it so many elements of frustration and defeat that mankind turns readily from its subtle dishonesties to the simpler idea that one may match strength with an enemy on the battle-field much easier than he may match wits with a world of dishonesty that denies him, on lofty and legal and preposterous grounds, the right to earn a living, to play a dignified rôle as a worker who returns a *quid pro quo* to life for his living, and to enjoy this brief span of years allotted to him before he descends to dust and ashes. War itself may assume the more honest aspects of warrior combat, with an honest assumption, at times, that this is an admitted appeal to opposing strengths and skill, and it is often a bitter disappointment to the soldier that a war in which he thought he played an honest role as soldier and citizen turns out to have been fought for the low motives of so-called statesmen, and that when the diplomats sit down to arrange the terms of peace all of the soldier's ideals are forgotten, and the talk is of theft and oppression to be arranged. Surely, an honest life, in which one may tell the truth oftener than sometimes, would be a life in which peace might be maintained and war prevented.

To-day the ghosts of ancient war gods have come back from Antan to dethrone truth and reason and science, and to restore the old reign of magic and emotion and might. More than any other group, the scientist must resent and combat the return of these gods from the shadowy limbo to which science, more than any other force, has dispatched them. Even while the savage war gods are killing and mutilating civilian populations as they have not been killed and mutilated since the Middle Ages, it is still one of the most pathetic of to-day's spectacles to see outstanding scientists paying outward homage to the discredited and preposterous ideologies imposed on countries by the ghosts of Alexander and Ares. Mars may, for a time, defeat Minerva *vi et armis*, but the doctrine that might makes right may be inspected in the light of the fact that man has conquered the world by his brain, not his brawn, and that brains have not been conspicuously an outstanding feature of military men.

If all of this sounds a bit pessimistic, or if it suggests, unavoidably, the attitude of the elders in whom the fire is dying down, it is, nevertheless, an avoidance of the hypocrisy of smugness. Certainly, all is not well on a planet which reeks with gunpowder, and in which blood runs on battle-fields and before firing squads; in which famine and starvation march beside luxury and waste; in which frank expression of thought invites retaliation and suppression. It is a compliment to scientists that a scientist may say to them wherein we all fall short of the ideals to which we are, in some way and to some extent, committed. The preacher who speaks as frankly may face excommunication for heresy; the lawyer may invite being barred from practice for undermining the dignity, so-called, of the law and the courts; the law maker may be

charged with sedition and treason; and in matters in general any of us might be branded as bolsheviks, the current term for anyone who disagrees with us on any matter whatsoever.

Yet, even though scientists are courteous enough to listen to a statement of their shortcomings, what is the point in stating them? If there is a point, it is that science moves forward as the performance of scientists improves, and that by seeing wherein we fail we have taken a step toward a better performance. It is especially desirable that the younger ones among us should see wherein we have failed, and that the new generation of scientists avoid, to some extent, our mistakes. The new generation may realize, as we have not adequately realized, how essential it is that the scientist be honest with himself and his associates, even though we may admit, with suitable blushes for our cynicism, that he should confine his expressions of honesty, in most affairs, to such a few and carefully selected persons as can appreciate honesty. The young worker may realize that courtesy is one of the assets of personality, well worth practising in scientific circles, and even admissible, without penalty, in most of the affairs of life. He may learn that one may, at least, have the courage to face the truth, even though he restrain his expression of it, and may thus avoid the sin of self-deception. A younger generation of scientists may even make a slight impression on the world's way of thinking, and perhaps nudge it a bit in the direction of better thinking.

After all, the ascertaining and expressing of truth is our business to an extent that ranges beyond the aims of most groups. Justice Holmes has said that the business of a judge is not to see that justice is done, but that the law is enforced. Doubtless he was right, but it is a depressing thought when one considers by what uninformed individuals laws are made. Certainly the business of business is to make profits, but it seems an inadequate objective in a cheerless sequence of depressions, failures and unemployment, the results of a planless economic system managed by persons who need only capital or credit to engage in business, and subjected to no other demand for qualifications. The business of medicine is to make people well or keep them well, but it has long been a matter of worry to conscientious and thoughtful physicians that they should cure the sick in order to return them to slums, poverty, vice and crime, knowing that, when they go too far astray, a society on which lies the primary guilt of neglect and stupidity will settle with the delinquent individuals by the too simple expedient of executing them. By comparison with these other occupations, the scientist's search for truth seems exceptionally desirable. Not infrequently the scientist contributes in highly practical ways to the betterment of life and living, but, unfortunately, he can contribute little and very slowly to the human race in the way of improvement in its thinking, nor can he ensure that what he contributes in other ways will benefit those most in need of the benefit.

If we could assure ourselves of one thing, we could view the future of humanity with some degree of optimism. If we could but be sure that in his progress from *Pithecanthropus erectus,* or such other primates as you prefer, if we could be sure that with all his ups and downs, with all the peaks and troughs in his curve of development, man has made some little progress in his development of intelligence, as he has in his learning, and has come even a little closer to a desire for and an appreciation of truth, we might go from this earthly scene with some expectation that in time the world would be a place in which truth might walk in safety. For the scientist realizes that in all things there is a time factor, and that we have a reasonable expectation that man will have the benefit of a quite

ample time factor. We can specify a thousand years, or ten thousand years, as probably available for the working of such other factors as may lead to real progress, could we but be reasonably sure that the curve of man's history shows any upward trend of definite progress.

Without too definite assurance on that score, the evidence, nevertheless, suggests that man may have made progress along the lines of greater intelligence. It is a complicated and not a clear-cut progress. By comparison with the other animals, the human primate has forgotten how to be a good animal, partly, perhaps, because he has, to some extent and in one way or another, sought to suppress what he called the animal in him, forgetting that, as a rule, animals have some admirable qualities. They do not wage war on their own species, they do not complicate their living by the making of laws and rules that fit no individual whatever, and in general they manage to live in herds, flocks and packs with little need for extensive blood purges. Even the highly social ants and bees seem to have no such inadequate and badly suited rules and regulations as call for the large-scale punishments, banishments and disciplinary action which man, this miscalled social animal, has elaborated. It has remained for man to make of property something other than a thing of use and enjoyment, and to evoke from it hatred, envy, jealousy, greed, theft, violence, racketeering, war and the other unlovely and niggardly vices and misconduct that characterize this animal that regards himself as a human soul of a quality superior to the human animal in which it is domiciled. Nevertheless, one might judge that from the ameba to *Pithecanthropus*, there was some growth in intelligence, and, somewhat hesitantly, might affirm that among modern mankind there were I. Q.'s higher, by our standards, than that of *Pithecanthropus*.

As regards the search for truth, the evidence of progress is gratifyingly better. In the entire city of Syracuse, the Roman soldiery could find but one Archimedes to slay. To-day a well placed bomb might slaughter dozens of scientists, and if there are still few of these of a stature comparable to that of Archimedes, nevertheless a judicious selection of the time and place might easily result in the destruction of a National Academy of Science, and bring to some appreciative aviation officer a well merited sense of satisfaction. So we may say, quite candidly, that in these matters we have made progress.

To the younger scientist we might say that, apparently, the law of compensation is still in force. We still pay in one way or another for what we get, and the art of living, seemingly, consists in seeing to it that what we get is worth what it costs. The too casual thought of a world dominated by the herd thinking of low I. Q.'s and the mental aberrations of high I. Q.'s have developed ideals which are definitely unsound. Although it has been impressed on the plastic minds of our childhood that wealth, fame and power are the desirable things in life, we have the testimony of history and of those who attained these things that they quite generally lead to grief and disappointment. Fortunately, the scientist is not likely to be disturbed by the problems of wealth. If he attain any measure of fame, he will note, unless he take himself too seriously, that there is no great nourishment in achieving what any first-class gangster achieves to some extent, and that the friendship and regard of competent colleagues are better things. The power he may wield is the power wielded, not by personalities with the gifts of oratory, military skill and ruthlessness, but the power of fact, truth and reality at work.

If his teaching has been sound, he will realize that we know very little of the truth about anything, that what we accept as truth at the moment is accepted with reservations to the effect that our successors will find it faulty in one

respect or another, and that one reason we tell the truth at times, but not always, is that truth is difficult to grasp by any finite mind dealing with infinite things. In time he may achieve a gratifying modesty.

This modesty will increase as he realizes that human beings are ill-prepared to meet the specifications of a scientist. The possession of initiative, imagination, curiosity, technical ability, keen powers of observation, soundness of reasoning, precision of thought, intellectual honesty, and moral courage is something not granted in any large measure to the sons and daughters of men. Some two or three of these things we may have, but certainly not all of them.

With whatever modest equipment of this sort he may have, and with a realization of his limitations, the young scientist may still feel that in his practice of the art of living he is driving no bad bargain in investing his time and energy and intellect in a search for small fragments of truth and reality. Life is apportioned, in more or less equal parts, to work, rest or recreation and sleep. The scientist is usually one of the fortunate few that have congenial occupations, congenial and interesting associates and comfortable beds. He is paid to satisfy his curiosity, a happy arrangement for those who have any curiosity. When he has found some truth he can publish it, provided it is of such a nature or so worded that it does not conflict with established mores or business interests. In this land of freedom of speech and of the press, he can tell the truth—sometimes. In that respect it appears that the American scientist is fortunate above many of his foreign colleagues who must, in this modern scientific age, confine themselves to the authoritarian pattern which science long ago rejected.

At this time there is uncomfortable evidence that the right to tell the truth is in great and growing danger at home and abroad. Since the World War, governments have become increasingly hostile to the telling of truth and to all thoughtful people, including scientists. Diplomats—the superlative of the old series of liars, damn liars and diplomats—and super-diplomats in the form of dictators dominate the world's thinking and expression of thought. In this country we are developing a mode of expression from which one notes, with surprise and discomfort, that among our magnificos, criticism of the ability and uncertainty of the honesty of, at least, some business men and business methods is regarded as a form of treason.

If truth and truth telling is in danger, it concerns the scientist. Is there any likelihood that the scientist will do anything about it? Very little. With some confidence, we can assert that the scientist will follow the classical pattern of Archimedes, and will draw his plans in the sand or work in his laboratory, as he is doing in Spain and China, until high explosive terminates him and his work. As individuals or as a group, scientists can be expected to do little about a world bent on making itself unhappy.

In time, however, the scientific method may be expected to prevail. When that time comes, when government, politics, religion and business put off childish thinking and adopt the methodology of honest search for fact, truth and reality, scientists may tell the truth, and not merely sometimes. When that time comes, probably anyone can tell the truth. And that will be most agreeable to us. For, after all, the ascertaining and telling of truth is the business of the scientist, and an honest world in which one might live honestly should not present problems for the scientist in adjusting to society.

OUR MUSCLES AND OUR MINDS

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WHENEVER a person says he used his "brain" or asserts that his "head" is tired, he implies a theory of the mental life which finds little support in current research. Ever since it first received official notice in the writings of Gall and Spurzheim this alleged mental organ has been overworked in the explanation of behavior. By popular acclaim it is the brain which thinks, controls our actions, tells us how we feel and what we should do about it. In such deifications it is easy to discern the vitalistic countenance of the "soul" hidden behind a set of neurological false whiskers. The discovery of the sensory areas of the brain was taken as inescapable proof of the point of juncture between the material and spiritual universe and it was thought that all the difficulties of consciously directed action could be met either by introspective analysis or by the surgeon's knife. This idea is now so generally ingrained that mental healing cults have made rapid strides forward in decades when scientific progress leads in opposed directions. For while popular interest in the mind-body problem has languished in a fixational complex for the brain, important developments have taken place in the laboratory.

It was not until the search for centers specifically associated with the higher mental processes suffered a telling experimental disproof that the brain's claim to mental determinism was seriously questioned. In fact, very little interest was displayed in what made it function in the first place. By implication, the mind was regarded as a *tabula rasa* upon which external stimuli might write as they pleased, and the matter of inter-neural dynamics was quite neglected in the zeal to concoct a palatable scientific stew out of introspective observations on the flow of mental life and the brain processes hypothetically associated with them. Repeated demonstration of the linkage of brain processes with the total neuromuscular reaction sequence finally brought us out of this state of intellectual coma. The idea that the brain can carry on its traffic more or less independent of the rest of the body is now generally recognized as inconsistent and myopic. Instead of being merely handmaidens and servants to the brain, the muscles are seen as important regulators and determiners of its function. Physiological psychology has moved on to the more promising task of finding out the ways and means by which the muscles affect mental activity.

It is now generally recognized that study of the dynamic relation between muscular action and mental process leads especially to those maintained states of slight contraction known as muscular tensions rather than to the overt "phasic" activities such as occasion the moving of a limb. The relationship has been approached experimentally from two directions: the first varies some phase of behavior and observes the resulting changes in muscular tension; the second alters the tension of the subject directly and observes its effect upon performance. Both procedures have been used extensively and with remarkably consistent results.

Individuals who persist in completing mental work that has been disrupted or who engage in a second line of behavior upon frustration of a first, are found to

have increased muscular tensions. Compensatory reinforcements by way of increased tension also occurs in combating the deleterious effects of protracted work, as when an individual shows no decrease in objective work output but has to increase progressively his muscular "energy" input. Performance following severe sleep loss is often continued without objective decrement due to the muscular accompaniments of increased effort. Heightened tensions and excitability resulting from irritating experimental situations correlate with self-ratings of emotionality.

But while annoying situations, new tasks and serious thwart to activity in progress raise the tension level—habituation, learning and removal of inhibition are accompanied by relaxation. Both in the acquisition of verbal associations and in the development of sensori-motor habits, it seems that the curve of work output and the curve of supporting neuromuscular action are inversely related. In the initial stages of learning gross tension is apparently necessary to accomplish a minimum of output. As learning progresses, increased performance is accompanied by reduced tension.

It should not be inferred that tension can be increased indefinitely without adversely affecting both the quantity and quality of performance. Many activities, such as playing golf, are rendered less effective under excessive tension. Such evidence suggests that "consciously" directed action is sometimes facilitated and sometimes inhibited by muscular tension. Analysis of this basic problem has come largely from experiments where tension is altered experimentally and its effects observed on some standard test performance. Under "progressive relaxation" there is a reduction in sensory acuity and reflex response as well as in more complicated mental activities. Experimental alteration of the postural state indicates that different types of activity are inflected from facilitative to inhibitory effects at different points on a scale of gradually increasing tensions. Excessive tension raises output in simple motor performances and increases sensory acuity, but is harmful to tasks involving delicate eye-hand coordination and reasoning. Influencing factors other than the amount of tension are its locus in relation to the bodily parts engaged in performance and its timing. With these matters under control it is possible to describe for a given individual in a given situation his efficient working level, where a maximum performance output is attained with a minimum muscular input.

These results suggest that the older notion of the brain controlling the rest of the body should be replaced by its converse. Mental activity becomes a purely relative matter—and that relativity is supported largely through the muscular processes. The highest degree of consciousness or level of adjustive response carries over a limited range of reactivity. Mental processes suffer as the supporting postural substrate falls below or exceeds these limits.

We must be clear of two misconceptions, else we miss the main point of this interesting relation. One confuses muscular power with the ability of the integrative mechanism to use advantageously excitation derived from the muscles. The other attempts to postulate a one-to-one relation between specific muscular processes and specific mental acts.

Until recently, most people would have treated as absurd any notion that their mental processes were as intimately related to their muscles as to their brains. When suddenly assured that this is the case, they have difficulty in orienting themselves to the changed notion. Unable to understand just why his muscles

should be of any more importance to thinking than his heart or his liver, the average man desires to be on the safe side so far as mental vigor goes. And since psychologists have been none too articulate in explaining the relation of mind and muscle, he listens, perforce, to the more voluble claims of the physical culturists. Forgetting that the old adage, "a strong back and a weak mind," may still hold, he often jumps to the fallacious conclusion that a beautiful physique in and of itself will develop mental power. As a result many muscular nostrums have developed. Chiropractic offices are filled with patients awaiting "adjustments" calculated to restore their vitality. Department stores show all manner of ridiculous contraptions for rejuvenation of various parts of the body. The correspondence courses in muscle building do a thriving business, and the "daily dozen" has become an excruciating feature of many an already harried life. The pathetic thing about all this well-meant but generally misguided effort is that it has accomplished little that it apparently hoped to do. Insomnia is as prevalent as ever and the number of insanities which can be traced indirectly to neuromuscular hypertension is on the increase. Individuals who should have been drugged to sleep have often been urged to exhaust themselves further, while others who needed some exercise have tried to take a "rest and quiet" cure. To the stupidity with which man has always abused his neuromuscular mechanism there is now added a latent and misdirected solicitude for it. Mere drill in the outward signs of muscular exercise and relaxation will have little effect upon the mental processes. For if these are sustained by a backlash of excitation from the muscles, as we have reason to believe, adequate adjustment becomes a matter of effective use of the excitation in neural integration and not one of potential power. Doctors can thus advise rest, exercise or change of scene without limit, but unless their patients learn how to control their own energies, the value of the prescription is questionable.

But if the layman has been mistaken in his notion of the relationship of mind to muscle, many psychologists now seem to have been equally in error. When the search for the bodily processes associated with thought finally led to the muscles, it was a great day for the behaviorists. Most motor theories of consciousness developed by this school turned to the postulates of the completed circuit of the reflex arc. Consciousness was said to occur only when sensory stimulation of the brain eventuated in some specific motor response. All that was required to produce this mental froth was for some muscle group to act "overtly" or "tentatively" or "implicitly" and so complete a specific circuit through the complicated neural switchboard.

This idea has been very attractive to many because it offered a simplified method for the objective study of mental activity. All they would need in order to find out what John Smith was thinking about was to record the movements made by his tongue and larynx. It is in no way clear, of course, just why any one should assume that the tongue must be in motion when a man thinks. Few of us would call the social gabbler a deep thinker; for we have often observed that a person who handles words most fluently has actually very little to say. Much true thinking seems quite inarticulate.

But thought was a great stumbling block to the theorists and it had to be connected with some *specific* motor system. It was fairly logical to assume that one had the consciousness of red because a peculiar retinal impulse passing into the brain was shunted out along a given pathway to the eye-muscles; or that we

experienced sounds because of the motor adjustments made by the auditory apparatus. In casting about for an unassigned group of muscles with which to link thought, one of the early behaviorists hit upon the larynx. The vocal apparatus of many individuals has subsequently suffered all manner of indignity in an attempt to verify this hypothesis. Movement analyzers have been tied to the tongue and the voice box prodded with sensitive needle electrodes. The results are all disappointingly negative. There is wide-spread muscular activity during thought (including swallowing and tongue movement), but there is practically no evidence that such activity is specifically localized in the throat.

Now we have seen reason to believe that some sort of muscular activity is an essential condition for mental activity. But the notion that each particular brain process is supported by activity in particular muscle groups is open to serious question. For one thing, it is neurologically naïve. There was a time when it was plausible to assume that the ringing of a special cortical "bell" was accomplished by the closing of a sensory-motor circuit through it. But it is now generally apparent that neural processes are much more complicated than this "reflex" theory of mind concedes them to be. The balance of evidence favors the view that the nervous system acts as a total integrated unit rather than as a mere aggregation of isolated pathways. The principles of irradiation, induction and altered excitability are more or less foreign to the analogies of the telephone system.

Another and more reasonable explanation of why muscular action is essential to mental action is reached by going directly to the nerve-cell. The brain is made up of a mass of these cells, each of which will respond in varying degrees to the same externally initiated energy change, depending upon its state of physiological readiness or "vigilance." The vigilance of a nerve cell is determined by the substances carried to it by the blood and by the excitations irradiating from other nerve centers. A cell may fail to react adequately when there is a lack of either nutritive material or intra-neural stimulation. Asphyxiation, narcosis and the presence of other toxic substances in the blood lower the efficiency of cell-reaction by lowering its vital condition. Lack of neural excitation irradiating from other centers seems to have much the same effect. It now becomes a question of where this intra-organic stimulation is derived. The proprioceptive excitation delivered into the central nervous system by the processes of muscular tension seems to supply a major portion of it. When the muscles relax, a great deal of the nervous current necessary to normal brain functioning ceases; external stimuli are relatively ineffective in eliciting responses in the absence of such reinforcement. Sleep results not so much from toxin substances in nerve cells as from the restriction of muscular activity.

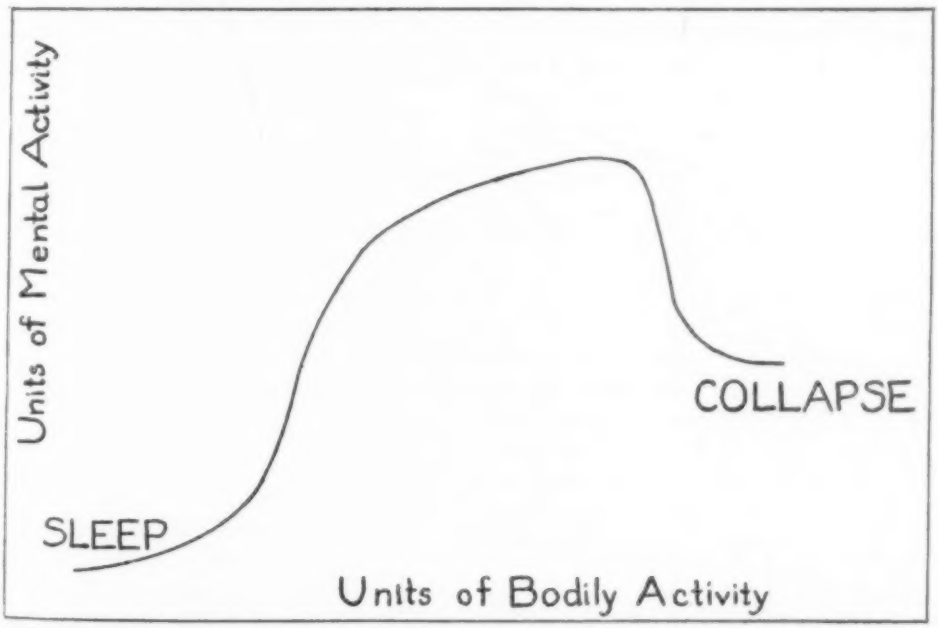
Let us state the idea in another way. The experience of a sound is dependent upon the excitation occasioned by an external energy source *plus* internal "energy" derived from the backlash of excitation from the muscles. We might go on to say that the experience can be heightened even further by increased muscular effort. This was exactly what occurred in certain experiments, where increased tension lowered sensory thresholds, shortened learning time and even compensated for lowered vital condition due to sleep-loss and fatigue.

We shall not stop here to detail how the summation of externally and internally developed energies might take place. For our purposes it is simpler to speak of the muscular processes as aiding

up to a certain point those higher nervous processes which we call mental, then affecting their disintegration in states of excessive reactivity. That these facilitative and inhibitory effects act to prepare for a given level of response adjustment rather than to complete an isolated neural circuit is an inference based partially upon the study of the spread of neuromuscular excitation, partially on the knowledge that the extrapyramidal (tonic) motor system anticipates and sets the stage for reaction of the pyramidal (phasic) motor system and partially upon the fact that no highly specific pattern of supporting tension is apparently present during mental work.

The dependence of effective mental action upon the character of the postural substrate has important general implications. While final confirmation is far from complete, it now looks as if this relation could be expressed by a function similar to that shown in the graph. This indicates that organic input increments (which includes the autonomic processes as well as the associated skeletal tensions) support increasingly effective performance up to a certain point, after which more excessive reactivity is accompanied by performance of decreased effectiveness. Performance levels maintained at the beginning of the curve would be akin to sleep whereas those at the end of the curve would represent complete mental and emotional collapse, though the height of performance attained and the range of reactivity covered would vary considerably with individuals. In all cases, however, it should be possible to describe as the most efficient working level, a point on the graph beyond which increments in organic input produce decreasing gains in performance.

If effective performance is judged as that occurring within the most efficient working limits of the average human machine, great will be the striving to keep within the proscribed bounds. Because



THEORETICAL RELATION BETWEEN THE EFFECTIVENESS OF "MENTAL" ACTIVITY AND THE QUANTITY OF SUPPORTING BODILY ACTIVITY.

of factors making for individual differences, one man may be able to work below the most efficient level of his individual curve and still attain the average proscribed efficiency for a given task. More serious will be the cases of men who must work beyond the efficient level of their individual curves in order to attain performance equivalent to that which superior machines can accomplish with less energy expenditure. Their systems are definitely overloaded and unless remedial procedures are instituted they frequently become headed for mental disorder and collapse.

It is not surprising that people who are fortunate enough to be absorbed in interesting work are inclined to give little attention to the drain being made upon their postural energies until their mental health is in danger of being impaired. This, however, is not the best time to attack a bad habit. The farther out of equilibrium that a reaction swings, the more difficult it is to reestablish balance. Our studies of the relationship between mental and muscular activity have brought us into contact with a large number of debilitated professional people. The question most frequently asked is "How can I make myself relax?" In most cases such people are working beyond their most efficient level of energy expenditure. The autonomic-glandular processes are beginning to contribute heavily in the mobilization of organic resource. These processes are more difficult to relax away and tensions which were apparently essential for handling certain difficult situations begin to persist after the need is discharged. The differential relaxation normally attained in reading a book gives place to a posture involving uselessly wide-spread bodily activity. The individual is often kept awake at night due to residual hypertension or related visceral disorders. Shortly there occurs changes in his mental attitudes and behavior indicating that he is losing his grip on a rational, highly integrated adjustment to his situation. He becomes irritable, peevish, emotionally unstable. His friends begin to avoid him and he himself may begin to think he is losing his mind. Then comes a conflict situation which taxes his power of adjustment as never before and he makes a critical failure. The various types of disorders which accompany this final state of collapse are well known to the psychiatrist. He, however, is like a captain called upon the bridge after the ship has started to sink. For just as a boat loaded beyond its "plimsoll mark" will not bear up through a rough passage, so an already overloaded human machine is likely to go down in trying to meet a difficult emergency.

It is proof of yet untouched areas that we know scarcely nothing about the mechanisms involved in the neuroses. Apparently two general factors contribute to the ability to withstand breakdown under load. One might be called the drive "libido" or potential bodily energies which can be mobilized for action. The other factor refers to the directional control, "ego" or degree of inhibition and coordination exerted by the higher nervous centers over the basic organic resources. The interrelation of these two factors will probably help to explain why some human machines react under load by regression to behavior characteristics of a lower than average energy level while others progress to the abnormal behavior of the hyper-active level. The basic answer lies of course in further research.

Meanwhile, what can be done for a person who is constitutionally more tense and "nervous" than the average of his fellows? For one thing, such individuals can seek lines of endeavor which will not

tend to emphasize this condition. Any work which sets an impossible pace or one which can not be mastered except by the greatest effort should be avoided. In case, however, that the individual is well launched on a difficult career and enjoys it in spite of its demands, he should take heart. A man of superior intelligence should not be urged to begin carrying a hod, simply because he experiences difficulty in meeting complicated situations with the calmness of some other people engaged in similar performance. Habituation to such work should produce some reduction in tension. Many individuals have acquired ease in their dealings only as the result of years of experience. It is only those whose "years of experience" have produced counter effects that are a serious problem. If each day's work is more exhausting, if each new situation is handled less adequately than the last, if each night's insomnia indicates the presence of more residual hyper-tension than the one before, then there is need for some drastic change in the organization of one's life. Small wonder that many individuals in such plight have subscribed to all manner of quack and nostrum. We can only wish that these had done as much good as they have harm.

There is one very bright hope for those who find themselves habitually tense and excitable. If such people can acquire inhibitory control and coordination of their activities in the face of a hyperactive postural substrate they may come actually to excel more phlegmatic individuals; if they can learn to harness their machine, it should produce not only *more* intellectual goods but also goods of *finer quality* than a sluggish machine. Many of our most successful men are dynamos of neuromuscular energy behind their surface of exterior calm. They are apparently separated from certain inmates of our state asylums by a rather narrow line. They have learned to coordinate and control rather than to dissipate and abuse. And the majority of them will say that they did this thing by themselves, not by the applications of a rubbing doctor.

COMMENTS ON CURRENT SCIENCE

By SCIENCE SERVICE[1]

WASHINGTON, D. C.

HARNESSING THE SUN'S ENERGY

The dream of converting sunshine cheaply into some form of practical power, such as electricity, is undoubtedly closer to realization than the release of the supposed power within the atom.

The earth's imports of solar energy are about all that it receives from outer space that is of any consequence. Immense quantities of energy are received. During the three months of greatest sunshine in the temperate zone, an acre of land receives directly from the sun an amount of heat equivalent to the burning of approximately 250 tons of high-grade coal.

Only a minute portion of this energy is captured and converted by plants growing on the land—some two or three tenths of one per cent. Our modern industrial civilization is possible only because inefficiently, but in impressive quantity, the past ages stored up sunshine in coal, oil and gas.

The search for more efficient solar energy utilization is being energized by Dr. Godfrey Lowell Cabot's gift to the Massachusetts Institute of Technology. Professors and students will be spreading a research net for new facts and applications.

The program has three directions: (1) Means for utilizing solar heat to operate engines to deliver mechanical power. (2) The possibility of converting solar radiation into electrical energy. (3) Chemical conversion of sunlight into forms available for work.

Mirrors might concentrate the sunshine and feed it to engines operating on small temperature range at low upper temperature, with small first cost and low maintenance.

Hope for electricity directly from sunlight lies in improving the low efficiency of vacuum or gas-filled photoelectric cells, thermopiles and boundary-layer apparatus, such as the copper-copper oxide cell.

There is possibility of eventually discovering chemical compounds that can absorb sunshine and convert it economically into stored energy.

RUBBER BEARINGS IN UNDERWATER WORK

Add rubber to your list of unusual materials now being used for surfaces of bearings. Copper, lead, babbitt metal, rarer cadmium and indium, even silver, are the best known members of the bearing family, for they all possess special properties of toughness, long wear, corrosion resistance or other desired characteristics. Flexible, yielding rubber seems a strange addition to this bearing family.

And yet, when you study the places where rubber bearings find usefulness the application of rubber is not too surprising. Pumping systems for drinking water and many solutions used in the preparation of foodstuffs or beverages comprise one application. A few others would include: high-speed motor boats, underwater marine work, hydraulic turbines, centrifugal pumps, agitators, washing machines and domestic and industrial liquid-handling equipment.

Secret of rubber's usefulness as a good bearing material is its ability to suffer

[1] Watson Davis, director, Frank Thone, Robert D. Potter, Jane Stafford, Emily C. Davis and Marjorie Van de Water, staff writers.

slight displacements and yet keep a tight fit. Thus a grain of sand or other hard particle only makes the rubber surface give and does not force the particle into the axle, or bearing surface.

As reported to the Institution of Mechanical Engineers in London by Sydney A. Brazier and W. Holland Bowyer, water or other fluid, and not oil is the lubricant with rubber bearings. A series of slots are provided in the bearing and the fluid passes, rather freely, through these interstices so that it can wash out dirt particles and also remove heat, for rubber's heat conductivity is so low that this factor is a problem in the use of these bearings.

As described in *Mechanical Engineering* the use of rubber entails no sacrifice in bearing life, for oftentimes a rubber bearing will outwear a metal bearing under the same service conditions.

"SHAPE" OF RAINSTORMS AND THEIR EFFECTS

Rainstorms have shape and structure, and these determine to a large extent their effects for both good and ill. This has long been realized in a general way, but it has not been until lately that even an approximation of close study of these highly important meteorological phenomena has been possible.

At the recent national meeting of the American Meteorological Society, the subject was discussed by representatives of two different parts of the U. S. Department of Agriculture: Dr. Merrill Bernard, of the U. S. Weather Bureau, and Dr. C. W. Thornthwaite, of the Soil Conservation Service.

One of the principal handicaps in the more minute study of rainstorm shape and structure has been the relatively wide spacing of observation points. The raingages and other instruments necessary for obtaining data have been located at cities scores or even hundreds of miles apart, with scattered supplementary stations maintained in smaller places by volunteer observers. Records have been taken, as a rule, only once or twice a day, so that a cloudburst of an inch in an hour might appear on the record as a 24-hour precipitation.

However, with the simultaneous advent of depression and drought, with relief consequently necessary for many farmers, the ill winds have been taxed for at least a modicum of scientific good. Weather-recording set-ups have been established in a thick network over a whole river watershed in Ohio, with a station kept by an instructed farmer about every four miles. Records can be taken every half-hour or even every fifteen minutes.

It has thereby become possible, after assembling and digesting the vast masses of data in central computing offices, to learn where the rain has fallen thickest and for how long. The extent and movements of the rainiest and the "driest" parts of a rainstorm have been traced, and quantitative figures of runoff, soil erosion, local floods and other long-desired but hitherto unavailable data have been obtained.

SOYBEAN VARNISHES

It is just a bit more than a year now since active work on most of the projects at the government's Soybean Laboratory at the University of Illinois got under way. And in that year America has been diligently trying to learn about soybeans.

Thirty-six different varnishes containing 100 per cent. soybean for their oil content have been developed and are now undergoing exposure tests to determine their aging properties, according to Dr. Henry G. Knight, of the U. S. Bureau of Chemistry and Soils, reporting in *Industrial and Engineering Chemistry*.

The acid, alkali and water resistance of many of these oils is excellent, adds Dr. Knight, who urges that some of them

appear to justify their immediate use for certain purposes. All that needs to be realized by the user in applying the new soybean varnishes is that their drying time is not as rapid as the super-quick lacquers which are so popular for many uses.

The work of the soybean laboratory is, in many ways, a race with increased production of soybeans by the American farmers. In 1926 only 2,646,000 pounds of soybean oil were crushed. In 1937 the crush will be near 200,000,000 pounds when final figures are compiled.

Soybean oil, oilmeal, soybean flour and other food stuffs are some of the products of the soybean tree. Among its industrial and food uses are: paints, enamels, varnishes, printing ink, linoleum, plastics, shortenings, margarine, foundry cores, livestock foods, flour, soy sauce, dietetic foods, infant foods and beverages. From the protein content of soybeans a leading automobile manufacturer is now making a synthetic fiber quite comparable with the Italian trick of using the protein in milk casein for the same purpose.

VITAMIN A IN DAILY DIET

Doctors and nutritionists tell you to drink plenty of milk and eat plenty of fresh fruits and vegetables every day in order, among other things, to insure getting enough vitamins. But maybe you have wondered how much is plenty. Having learned to count your calories, perhaps you would like to be able to count your vitamins instead of guessing at them.

Vitamins are measured by what are called "units," a unit being the amount that will produce a certain definite effect in a laboratory animal that has been deprived of the particular vitamin. As vitamin chemistry has developed, scientists have been able to define units in more mathematical terms, which has greatly simplified standardization and dosage of vitamin products. The International Unit of Vitamin A, for example, is defined as the "growth-promoting activity of 0.0006 milligrams of crystalline beta carotene." Carotene is the stuff from which the body makes vitamin A.

An adult should eat at least 3,000 vitamin A units daily in order to remain healthy, avoid night blindness and be better able to withstand infection. More than 3,000 is desirable.

You can get 670 units of the daily 3,000, says the National Dairy Council, from a generous, six-to-quart-size serving of ice cream, 700 units from an ounce of cheese, 1,040 units from a pint of milk and 1,600 units from one and one half ounces or about three tablespoons of butter.

Getting over to other foods, you get 1,000 units of vitamin A from one ounce of raw carrots; 3,000 units from an ounce of liver; 3,000 from an ounce of spinach; 700 units from an ounce of squash; 800 units from an ounce of fresh prunes; 1,000 units from an ounce of eggs; and from good old cod-liver oil, 8,280 units from one teaspoonful.

THE HOSPITAL FOR MENTAL DISEASES IN VIENNA

Few scientific discoveries have the dramatic thrill for mankind that is possessed by certain epoch-making medical discoveries. The story of lives saved by insulin as a cure for diabetes, by liver for pernicious anemia, and, most recently, by insulin again as a cure for dementia precox have the heart-touching appeal of modern miracles.

Among these medical wonders is the tale of the conquest of paresis.

Paresis is particularly tragic because it attacks men in the prime of life, robbing them of health, happiness and sanity itself and leaving them to a slow horrible death. It was once called Officer's Dis-

ease because it would develop in those army men in the higher ranks who remained for a long time in the service. Enlisted men who left the army after their service was done, did not come under the observation of army physicians after the paresis had had time to develop.

First hint of the cure came also from the experience of the army. For it was observed that men returned from the tropics did not fall victims to this disease. It was at the Hospital for Mental Diseases in Vienna that Professor Wagner von Jauregg discovered that the tropical fever malaria would kill the organism responsible for paresis.

As a result of this discovery, just about a third of the formerly doomed paresis patients, as treated with the malaria therapy in the United States, may now get well and go home again.

Recently the Vienna hospital celebrated its 30th anniversary—now, as at its founding, one of the most modern institutions of its kind. Segregation of patients according to their condition, social rooms, theaters and modern equipment and treatment make the outlook for the patient favorable. A special wing for alcoholic cases exclusively and a bureau for the supervision of alcoholic outpatients are innovations.

The Vienna hospital reviews an enviable past. What will the future hold?

PREVENTABLE SMALLPOX

If there is any disease that it is almost criminal to have, that disease is smallpox. Ever since the time of Jenner, the simple process of vaccination prevents it at trivial cost and inconvenience.

America's largest city, New York, has been entirely free of smallpox since 1932 and no one has died of that disease there since 1926. That can hardly be said about any other human ill. But the United States is not free from smallpox. In fact, this disease is on the increase. There were 11,806 cases in 1937 as compared with 7,844 the year before, according to Metropolitan Life Insurance Company figures.

This is disheartening to medical authorities. A few years ago it seemed that the disease was at last coming under control and would be eliminated as a major health problem. Fortunately, the form of smallpox prevailing in the United States is mostly the mild, nonvirulent type which causes relatively few deaths. But this mildness may change to a more deadly form, killing hundreds or thousands before vaccination stops the march of a serious epidemic.

It is not the congested areas of the East that constitute smallpox's stronghold. The record of the past five years shows only 256 cases in eight crowded eastern states, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland. There were 14,203 cases in eight less populous states in the opposite corner of the U. S. A.—Washington, Oregon, Idaho, Montana, Wyoming, North and South Dakota and Nebraska. The contrast was one case per million of population as against 428 cases per million.

This difference is merely a matter of how widely vaccination is practiced. For smallpox flourishes in every clime and country if given the chance. Evidently only a devastating epidemic of the more dangerous kind of smallpox will teach a costly lesson where vaccination is lax.

SCHOOL BOOKS AND DISEASE GERMS

Every so often in some community comes up the question of disease germs being spread by school books. This is only natural, since books handled by patients having tuberculosis, scarlet fever, diphtheria, meningitis, infantile paralysis and kindred diseases are more than likely to get some of the germs on them either from the patient's breath in sneezing or coughing or from his hands.

A pretty clean bill for ordinary school books, however, and some recommenda-

tions on books in general are now presented by Arthur H. Bryan, of the science department of Baltimore City College. He collected pages from very old and from newer school books, most of which had been recently used by students, cut up the pages, soaked them and shook them in sterile water for from 15 minutes to one hour, and then transferred some of the water to germ growth media to get some idea of how many germs actually had been on the pages of the books.

Ordinary school books, surprisingly enough, showed very few germs and those mostly of a harmless variety. Books that are not too old or dilapidated, he concluded, are not serious carriers of infectious diseases. School books that are kept for some time before being redistributed do not seem to have many living disease germs on their pages. Old books with visible dirt and grime smeared over their pages are capable of harboring many more disease germs than clean or new school books.

Mr. Bryan recommends that old school books which are frequently exchanged should be opened up and sunned for several hours. Books used by sick children should not be handed out to other students immediately (most germs die or lose their virulence if kept away from body tissues for a while). Books which are dilapidated, out of date and filthy with grime should be destroyed. Books coming back from quarantined homes should be destroyed or held for several months before redistribution.

WORRY AND TOOTH DECAY

Worry makes the teeth decay. That may seem like a far-fetched statement, but it appears to be a logical enough conclusion from a recent study at Cornell University by Drs. A. L. Winsor and Barney Korchin.

Upsetting the dicta of older physiology textbooks that the saliva in your mouth is naturally alkaline, the experiments of these investigators, carried on over a year, indicate that instead the saliva is naturally somewhat acid.

When the flow is increased, as it is by chewing or by appetite, this acid content becomes diluted—the saliva is less acid.

But remember how your mouth feels when you worry or are angry? It is dry. Your tongue "cleaves" to the roof of your mouth. That means that the normal flow of saliva is cut down, and with the lessening of the flow the acid content is increased.

The degree of acid remains proportional to the flow whether your mouth waters from the odor of broiling beefsteak, or the smell of pickles, or merely from chewing on a hunk of bubble gum, these investigators found. The greater the flow, the less the acid content.

But after prolonged mental activity, when you are very tired, or after you have been asleep, your saliva is more acid, the Cornell investigators found. The secretion that accumulates in the glands during rest periods is less acid if the previous flow was plentiful.

So great is the effect of making the mouth water that the secretion can be changed from acid to alkaline in less than one minute, they found.

"A possible relation between these data and the recently reported studies of dental decay and nervous upset was suggested," conclude Drs. Winsor and Korchin.

THE EMOTIONAL BREAKDOWN OF A CAT

It may seem a long step, psychologically, from a cat whimpering in a box to a young student who throws down his books and bursts into an emotional storm. But is it? Let us look further into the story of Tom the cat as told by Dr. Harry W. Karn, of the University of Pittsburgh, in the current issue of the *Journal of Experimental Psychology*.

Tom was a willing, docile cat. Being a laboratory cat, he had lessons to learn,

but he undertook them readily. The task, suited to his feline powers, was this: He must run down a center alley of a maze box, turn right around a hollow square to his starting point, repeat this maneuver a second time, and then follow a similar course to the left twice—twice right and then twice left. A reward awaited after each correct turn.

The second turn to the right was always the hardest for Tom. At one time during the early stages of his education, he fell into the way of turning right, left, left, right, and he persisted in this wrong habit for about 75 trials. Gradually he learned the correct pattern of right, right, left, left, however, and in 230 trials he built up an accuracy of 90 per cent. He was a grade B pupil.

But his teachers wanted to see whether he couldn't earn an A. So they persisted. At the second turn in the 232nd trial a radical change came over Tom. He hesitated much longer than usual at the turn and then jumped and raced around. After that he refused to enter the box. He scratched and clawed at experimenter and maze. He would not work. And he howled.

Only twice in 32 trials did he make the right turns. He went back to that old wrong pattern of right, left, left, right.

What had got into Tom? Whatever it is, psychologists would like to know, because we have seen the same thing happen to many a human Thomas. Willing, docile and reasonably successful, up to a certain point, they suddenly fly off the handle; they go back to childish ways of behaving; they strike out at those around them; or, like the cat, they cry.

FOSSIL SNAKES

Snakes are a comparatively new thing under the sun. In the Age of Reptiles, that ended only 50 or 60 million years ago, they were almost unknown. Only the last of the dinosaurs, that lived in Cretaceous times, ever had a chance to see snakes, and those were of the earliest models and probably not numerous at that. At least, their fossils are exceedingly rare to-day.

Data on the relative recency of snakes are included in a new monograph on "Fossil Snakes of North America," written by Charles W. Gilmore, of the U. S. National Museum, and published by the Geological Society of America.

The first snakes were non-poisonous, resembling modern blacksnakes and boas in that respect. Venomous species did not appear, so far as the present record shows, until Upper Miocene time, roughly from 13 to 18 million years ago. First rattlesnakes began buzzing in the geologic period immediately after that, the Pliocene, which lasted from 13 million years ago until the Ice Age began, about a million years back.

The prize specimen in the collection studied by Mr. Gilmore is the practically entire skeleton of a snake embedded in a slab of shale from the Green River formation, in the northern Rockies. Because of the slenderness and fragility of snake bones, it is rare to find well-preserved fossils at all; no skeleton so nearly complete as this has ever been discovered. Technique combining the skills of sculptor and dentist was necessary to free the fine bones from their stone matrix, but it was finally accomplished without mishap. This early invader of the American Eden was a serpent a couple of inches over a yard long. It has been given the scientific name *Boavus Idelmani*.

THE LONGEVITY OF BIG TREES

Honors for greatest age among living things are re-awarded to the Big Trees of western America in a summary study by the late Dr. Hans Molisch, formerly director of the Institute of Plant Physiology, the University of Vienna. Dr.

Molisch's book has just been translated and published in English by an American botanist, Edmund H. Fulling, editor of *The Botanical Review*.

The Big Tree's only close competitor for record length of life, in Dr. Molisch's tabulation, is the baobab tree of Africa, which is given an estimated age of 5,000 years. However, this is only an estimate, whereas the equal age of the Big Tree is backed up by actual counts of annual rings in the trunk.

Next in line come the banyan of India, sacred for having sheltered the Buddha. The identical tree under which Gautama sat when inspiration came to him is still pointed out, and since it has been a holy place during all the centuries, it is quite probable that the tradition is accurate, so that the estimated 3,000-year age of the "bo-tree" is well supported.

Not so well fares the giant cypress of Tule, in Mexico, at which stout Cortez marvelled, and which the famous German traveller, von Humboldt, estimated to be 4,000 years old. "Comparative estimates have indicated, however, that this swamp cypress can scarcely be more than 2,000 years old," says Dr. Molisch; "further proof that estimates alone easily lead to inaccuracies and exaggerations."

Even more drastic scaling-down in estimates had to be made for the age of the great dragon-trees of the Canary Islands, likewise claimed to be the world's oldest. Dr. A. Putter, who studied these trees critically shortly after the World War, would grant the oldest of them no more than 185 years. The claims of 5,000 or 6,000 years, advanced by natives for their trees, Dr. Putter dismissed as trivial, because the same natives "not infrequently do not know their own ages nor those of their children."

OUTLINING THE ROMAN EMPIRE

When ancient Rome was in power, the civilized world knew well enough where the guarded frontiers of Roman empire ran. To-day, it is taking the eye of the camera looking down from an airplane to find obliterated lines of that empire.

Work of mapping the whole Roman Empire was started in 1930 by an international commission of geographers. Since then various countries that control regions of the one-time empire have helped with the problem.

Ruins of old forts and roads and embankments have to be studied by the slow, hard process of excavation. But it is the flying archeologists who have been scouting out the lay of the land for the excavators, and mapping for them the most elusive lines of lost frontiers.

In Syria, a French archeologist, Père R. P. Poidebard, has done much to trace Roman fortifications from Bostra eastward toward the Tigris. His interest in aerial photography goes back to 1926.

Père Poidebard has learned by experience that in this desert country ruins appear and vanish even so far as the sharp eye of the camera is concerned. Not only the season, but time of day and weather conditions affect sighting of phantom ruins.

Early morning and late afternoon light are best for sharpening the shadows and bringing out obscure patterns of ancient handiwork buried lightly in the earth. Yet, the French observer has outwitted the sun on occasion, making hidden ruins visible near midday by the trick of flying low and using the plane wing to shadow the ground. The first time he used this technique, he detected an ancient road leading toward the Tigris River, that previous observers had missed. Once spotted, the ruins are marked on maps, and then the spade expeditions go out, to learn more about the frontier defenses in which ancient Rome put her trust.

FEAR IN AINU WOMEN

The happy savage is not so happy, after all. Jean Jacques Rousseau gave

the world a rosy picture of primitive life. And ever since, the popular notion has persisted that primitive man has no fears and worries. At least, none worth mentioning in the same breath with the city dweller's harassed nerves.

But scientists are finding that primitive man and his wife do fret. Get close enough to some native group, and you may find ugly mental and nervous disorders preying on individuals. What particularly interests the psychiatrist is that a primitive group has its own peculiar forms of mental and nervous abnormality.

A curious fear reaction that besets the Ainu race has been studied lately by three Japanese psychiatrists. Out of 17,500 Ainus, who inhabit Japan's most northerly islands, 111 women were found suffering from abnormal susceptibility to fear. Over half owed their condition to some fright over a snake, in the past.

Whatever caused the trouble—fright at a snake, frog or other creature—the same object would at any time cause the victim to go through a routine of queer behavior. Even mentioning a serpent was enough to start an attack in some women. The terrified Ainu would grow hysterical, fall into a cataleptic fit, reduced for several minutes to automatic and abnormal behavior. In the past, this condition, called imu, was said to be more prevalent than now. Both sexes were affected.

The Japanese doctors conclude that this hysteria, which differs from the usual forms of hysteria found in civilized life, is a primitive form, and even goes back to the prehistoric era of Ainu life.

DIFFICULTIES OF RIVER REGULATION

America is not the only land where ill-advised "improvements" to rivers have brought loss and trouble in their train. Some of the older countries made their mistakes earlier—and have had longer time to be sorry for them.

A clear-cut example is furnished by the wide flood-plain lands of the lower Danube, on the estate of Count Traun, one of the great landholding nobles of Austria. Until the end of the eighteenth century the river floods were allowed their own way on the flatlands. They deposited fertile silt, which made for lush growth of vegetation and rich forests.

Then, early in the nineteenth century, the river was "improved." Its channel was straightened, and levees were built to keep its floods away from a large part of the former overflow lands.

To-day the consequences are tragically evident. The protected lands back of the levees have been stripped of their forest cover, where they had it, and all of the land has been so intensively cultivated that the alluvial soil has been "mined" of its plant nutrient wealth. And of course, no new silt deposits can be brought by the river to renew it.

Between the levees the condition is even worse. The river, in its straightened, narrowed channel, rushes through rapidly. When high water occurs, it boils out into the restricted flood plain that has been left to it. Long since, it carried off the rich surface soil it had once deposited. In its stead, the river now dumps gravel and coarse sand. The land that was once almost tropically luxuriant meadow and swamp forest is now a tortured, sterile desert.

The loss is felt by everybody concerned. The present-day Counts of Traun get less income and have less hunting in the lowland thickets. Their peasant tenants harvest less hay and have less wood to burn. And the impoverished treasury of Austria collects less taxes.

THE WORK OF BEAVERS

By EDWARD R. WARREN
COLORADO SPRINGS, COLO.

In studying the work of beavers even though for the most part in a few localities as I have done for a considerable number of years, many things of special interest are found sometimes quite new, and again, though not especially new, yet worthy of recording. There are two streams some fifteen miles northerly from my home in Colorado Springs—Monument Creek and its tributary, Beaver Creek, where I have studied the beavers more or less continuously since 1913.

Dugmore, in his "Romance of the Beaver," mentions a dam in Newfoundland, where, during high water, the beavers removed part of the crest of the dam, thus forming an opening or spillway through which the water escaped, relieving the pressure on the dam and possibly saving it from destruction. I must confess that I was somewhat sceptical about this, but have since seen an instance where I had little doubt that the beavers had done just that very thing, and not only on one dam but on three successive dams. This was on the 23rd of April, 1926, on Beaver Creek, at a time when the stream was high from melting snows at its head. Here were three dams, one above the other and some distance apart, and each had a gap in it through which the water escaped. This gap was in each of two cases seven feet wide and about a foot deep (Fig. 1). I did not measure it on the other dam, the lower of the two. At this one, on May 14, I found that the opening had been deepened so much that the pond was drained, and remained so for a year or more, when the dam was rebuilt, though somewhat differently from its original form. After the high water had subsided the gaps in the two upper dams were closed and the ponds refilled, maintaining a varying existence for a few years. It seemed to me that these openings must have been purposely made to relieve the pressure on the dams.

Farther up the stream on the same day of April, I found another dam where the stream had broken through, and pushed a tangled mass of the material of the structure out and down. This mass was nine feet long up and down stream and about six feet wide. The opening made by the water was eight and a half feet wide, and was from three to four feet deep. A week later there was no special change, but on the 14th of May I found that some sticks and trash were across the bottom of the gap and the pond was filling a little (Fig. 2). By the 22nd the beavers had built up to within fifteen inches of the top of the dam and there was plenty of water in the pond. Later the dam was built to its former height. A few years after this the dam was again broken, this time near the left end, and never repaired. As new dams were constructed farther upstream I presume that that is where the beavers went.

The spring of 1926 seems to have been a time of catastrophe to the beaver dams on Beaver Creek, for again on the 23rd of April, when I went upstream from the last-mentioned dam I saw still another which had been broken by the high water (Fig. 3). This I did not examine particularly until early in May, when I found an unusual construction. The diagram (Fig. 4) will help to make this clear. The right section of the dam went

FIG. 1. DAM NO. 13, BEAVER CREEK, APRIL 23, 1926. SHOWS THE OPENING OR SPILLWAY IN THE DAM. DAM NO. 14 CAN BE SEEN ABOVE, WITH ITS SPILLWAY SHOWING IN THE UPPER CENTER OF THE PICTURE. DAM NO. 15, WHICH ALSO HAD A SPILLWAY, WAS ABOVE AND DOES NOT SHOW.

directly downstream twenty-four feet to the break, and thirty feet to the left section of the dam that had been forced out by the water and turned around so that it was continuous with the other part. There must have been great pressure to have accomplished this, and it is remarkable that the dam should have held together instead of breaking up and going downstream piecemeal. This is, however, not the only occurrence of the sort that I have seen. A study of the situation here indicated that once the dam extended straight across the stream from the upper end of the portion now extending downstream, and it seemed as if some preceding flood had moved that 24 feet around to the position in which I found it and that the beavers may have then built the dam around from the left end and made a connection. Later on the beavers repaired the gap and filled the pond. In 1929 the pond was finally abandoned.

In October, 1934, I found on Monument Creek something totally unlike any other work of the beaver that I had ever seen. A dam across the stream had been broken, the pond drained, and the shallow stream flowed along near the right bank. At the left bank, a hundred feet above the dam, was a curved embankment, evidently built of mud dug from the bottom and making a pool forty-two inches wide by twelve feet long, and six inches deep and filled with muddy water (Fig. 5, upper left). At this time the lower part of this bank was dark and wet, as if put on the previous night. The greatest width of the bank was four feet. From the lower end of the pool a trail eight feet long went down toward the creek. A burrow was discovered in the bank near the upper end of the pool, and here the beavers were probably living, having constructed the pool rather than abandon the empty pond. In December the pool was frozen solid with no signs of life about it.

On the same day that I found this pool

FIG. 2. ABOVE: THE GAP IN DAM NO. 16, FROM THE POND. THE PICTURE WAS TAKEN ON MAY 14, 1926, AND SHOWS THAT REPAIRING HAD BEGUN. BELOW: THE SAME VIEW TAKEN A WEEK LATER, SHOWING THE PROGRESS OF THE REPAIR WORK.

I came to a dam forming a pond perhaps fifty yards in length. At the left side of the stream, about a hundred feet above the dam, was an indentation or bay. Here there was usually water next the high bank, and bare ground between the water and the stream. The beavers had made a canal starting from the upper side of the bay, curving around through the flooded space, mud banks piled on each side, with a very muddy trail from its end down to the pond. Where I measured it the canal was thirty inches wide, and the water was from nine to fourteen inches deep (Fig. 5, lower left and right). The right bank was continu-

ous from the upper to the lower end of the ditch, but the left one began a few feet from the shore; then there was a bank about ten feet long, then a gap below which a short dam extended out from the shore. From the end of the dam the left bank was continuous to the end of the canal, and approximately parallel to the other side.

Freshly cut stumps were at the upper end, whence a much-used trail crossed to the pond above, cutting across a bend in the stream and entering the next pond above at the left end of its dam. The previous April this dam was broken and the pond empty. In October I found that the dam had been repaired and the pond was full. In the winter neither the canal nor the trail seemed to be in use.

I found an interesting example, of the return of beavers to a pond they were forced to abandon, near Brush Creek, in the Elk Mountains of Colorado. I first saw this pond in August, 1930, when it was full of water. Its supply came from a small stream flowing down a steep mountainside. The pond was irregular in shape, approximately 160 by 340 feet in its dimensions. The north side and west end were formed by a long dam, the south side by a steep hill, whose base the water touched, while the inlet came in at the easterly end. The outlet of the pond was at the westerly end and flowed into Brush Creek a short distance away. This was to the north of the pond at a somewhat lower level. A lodge near one side of the pond was almost hidden by the willows growing about it, which would indicate that it was a rather old structure.

The following August, 1931, I again visited Brush Creek, and as I looked from my camp toward the pond a half mile distant, it presented a very different appearance from that of the previous year. Instead of appearing to contain water it had a whitish look, as if empty and dry. This proved to be the case when I visited it in the afternoon. Not a drop of water was in the pond, and the clay bottom was a network of cracks. The explanation of the lack of water was quite simple. The inlet derived its sup-

FIG. 3. THE GAP IN DAM NO. 18, BEAVER CREEK, APRIL 29, 1926, SHOWING WATER RUSHING THROUGH.

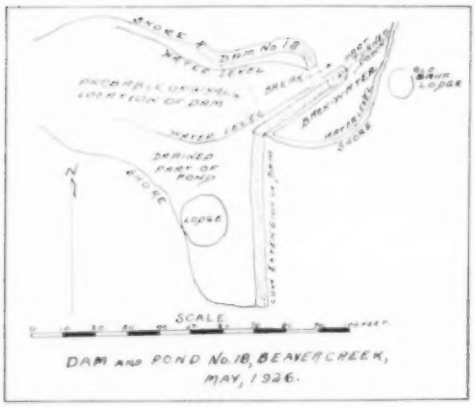


FIG. 4

ply of water from the winter's snow. The snowfall of the winter of 1930–31 had been unusually light, and consequently the stream had failed. The pond received no water, was presumably emptied by leakage about the dam, and dried up. I suppose the inhabitants moved to the creek and lived in the banks.

The house was eight feet high above the pond bottom and had seven entrance holes. The base measured about twenty-six by forty-five feet.

My third visit was made in August, 1932, and as I looked toward the pond from camp I could see that it was full once more. The usual heavy snowfall had come during the winter of 1931–32, and now there was plenty of water in the inlet. I visited the pond in the afternoon and found that the beavers had moved back, and had evidently resumed their usual routine of living. The willows about the pond had grown very much, and I found it impossible to go along the top of the dam because of their luxuriant growth.

It seems to have been a rather popular notion that beavers build their dams with an upstream curve in order to better resist the force of the current. My own observations show this to be a mistaken idea, and that the curvature of the dam is more likely to be downstream than up. Of twenty-eight dams on Monument and Beaver Creeks whose

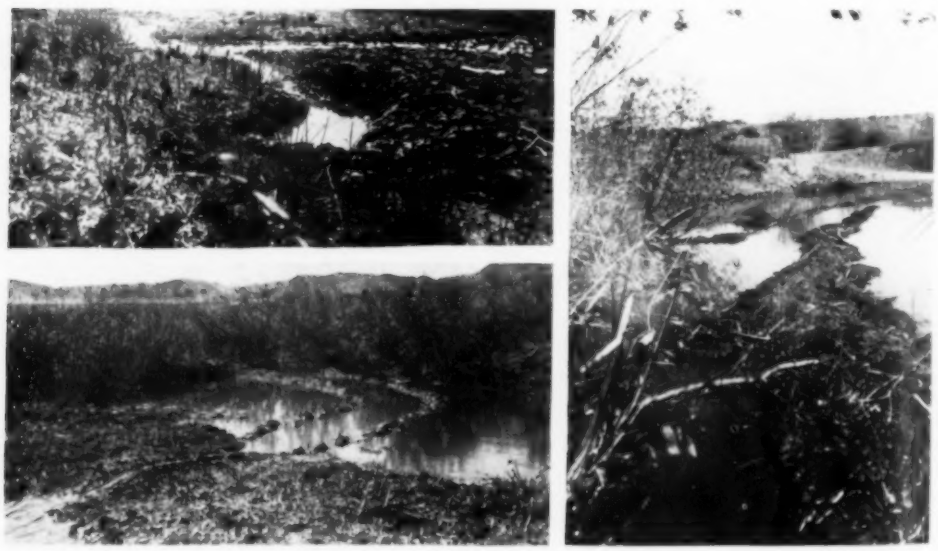


FIG. 5. UPPER LEFT: THE POOL FROM THE UPPER END. OCTOBER 24, 1934. LOWER LEFT: THE CANAL FROM BELOW. OCTOBER 24, 1934. RIGHT: THE CANAL FROM THE UPPER END.

curvature I noted, five had an upstream curve, eighteen curved downstream. Five others curved both ways. All told, seventy-seven dams were examined, many of the shorter ones were built straight across the stream, and a few were difficult to classify.

Floods may wreak wholesale destruction on a beaver colony. On Beaver Creek, between the date of my first visit, November 6, 1925, and up to May 28, 1929, I had found seventy-eight dams and ponds which were in use at one time or another during this period. In the winter of 1928–29 I found forty-five ponds were in use. At the head of Beaver Creek, some five miles above the uppermost beaver ponds, are six artificial ponds known as Carrol Lakes. On the 25th of July, 1929, an unusually heavy rainstorm occurred above the lakes, and such a volume of water flowed into them that three of the smaller dams were broken and another partially destroyed. The flood came down through the beaver colonies about nine o'clock at night, and destroyed every dam on the stream.

The owner of the land went to the stream the next morning to inspect the damage, when the water was still very high. He told me that he saw beavers swimming and trying to make their way against the current until they were exhausted and had barely enough strength left to get ashore. He thought a good many beavers must have been killed by the flood. Very possibly some were drowned in their burrows, caught before they could escape.

PARLIAMENT BUILDINGS IN OTTAWA, ONTARIO, FROM THE QUEBEC SIDE

THE PROGRESS OF SCIENCE

THE OTTAWA MEETING

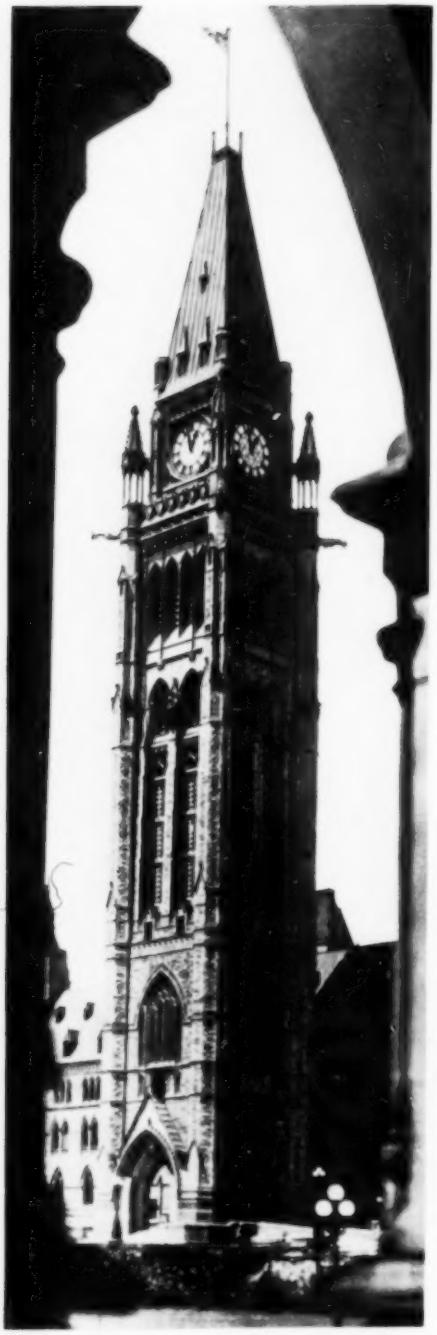
With a registration of 1,104 scientists and visitors, the Ottawa meeting of the American Association for the Advancement of Science, from June 27 to July 2, became the third largest summer meeting of the association. Only the Chicago meeting, held during the Century of Progress Exposition in 1933, and the joint meeting of the association and its Pacific Division, held in Berkeley, California, in 1934, were larger.

Approximately one hundred different scientific sessions were held during the meeting at Ottawa, and approximately five hundred papers were presented, about two thirds of them by Canadian scientists. No distinction was made, however, between scientists residing in Canada and those residing in the United States, for the association is truly American in the broad sense of the word. Perhaps the most important characteristic of the meeting was its entire freedom from any national considerations except in so far as the subjects treated were geographical in nature. The scientists of Ottawa were simply the hosts of the meeting, as the scientists of any city in the United States might have been. That a large part of the papers presented were by Canadian scientists was due partly to the fact that on the whole the Canadians did not have so great distances to travel, and partly to the fact that in Ottawa, the capital of Canada, there are many scientists in the technical bureaus of the government. For the same reasons of convenience the registrations of scientists from states near the Canadian border were much greater than from those that were more remote.

All general discussions at Ottawa of the benefits of science were in terms of humanity as a whole rather than in terms of any special political units. Some of the most important programs of the meeting emphasized that science is, or at least should be, above all considerations of national boundaries, races, languages and creeds. For example, the Science and Society program included papers on such subjects as "World Standards of Living," "World Natural Resources," "The Botanical Sciences and the Future" and "Physics and the Future." In the program of the Section on Chemistry there were papers on such subjects as "Medical Biochemistry" and "The Applications of Isotopes to Biochemical Problems." In all these discussions there was no national or sectional secrecy, but a world outlook; no restrictions by copyrights or patents, but pride in generous contributions to the welfare of humanity. A disturbed world needs many more international meetings in which nationalities and races and creeds sink into insignificance in the presence of larger objectives. Can it be that science because of its biological teachings of the universal brotherhood of man, the objectivity of all its methods and the unselfishness of its aims can inspire humanity with a spirit of productive cooperation instead of destructive conflict? If it can it may in this way be of greater service to mankind than will be all its remarkable technological applications.

There were, of course, programs at the Ottawa meeting which were geographic in character or limited in application. For example, the Section on the Zoological Sciences organized and presented a program on the migrations of the salmon which spawn in North American streams and rivers. After hatching they soon descend to the sea, where they spend all their lives until, guided by some strange influence, they return to the localities of their birth to produce a new generation and to die. The program of the Section on Engineering contained a paper on the collapse last winter of the Falls-View Bridge at Niagara Falls, another on gold mining in Canada and, for variety, another on flying boats. The Section on Historical and Philological Sciences presented a program of a com-

PARLIAMENT BUILDINGS IN OTTAWA, ONTARIO, FROM THE QUEBEC SIDE



PEACE TOWER OF THE PARLIAMENT BUILDINGS

prehensive history of Canadian science, which if published will be of great value in the future to all who are interested in the growth of science in Canada. The Section on the Medical Sciences presented a symposium, all by Canadian speakers, on "Bacillus Calmette-Guérin," which is the organism from which is produced a vaccine against tuberculosis. The Section on Geology and Geography had an extensive and excellent program built up around such general topics as the geographical characteristics of certain parts of Canada, the mineral industries of Canada, very ancient Canadian rock formations and their economic significance and such geographic problems as raising crops north of sixty degrees of latitude. The entomologists and foresters recognized the eternal struggle between insects and other forms of life, particularly man, in their symposium on "The Relation of Insects to Forest Conservation." Several sections and societies joined in a symposium on "The Genetics of Pathogenic Organisms," which included discussions of the genetics of viruses, protozoa and bacteria.

There were programs of quite different types by the sections on anthropology, psychology and education. The astronomers, as usual, concerned themselves with objects so far away that light comes from them to us only in the course of thousands of years. But their programs illustrate the fact that the fundamental unities which science discovers include the universe beyond our earth and our solar system. And all this diversity of subject-matter, presented at one place and at one time, with each part being influenced by every other part, illustrates the broad interests of the association and the unparalleled opportunities it has for serving science and society.

F. R. MOULTON,
Permanent Secretary

JOHN JACOB ABEL

THE death of Professor John J. Abel on May 24 ended one of the most productive, exemplary and successful lives in the modern scientific world. As he had hoped, he died as did his revered teacher, Oswald Schmiedeberg, "in harness." Busily working in his laboratory until shortly before his last illness, death came suddenly from a coronary occlusion during his convalescence from a mild attack of pneumonia.

John Jacob Abel was born near Cleveland on May 19, 1857. At an early age he showed a keen desire for learning and at nineteen entered the University of Michigan from which he was graduated with the degree of Ph.B. in 1883. His college work was interrupted for three years during which he taught mathematics, physics and chemistry and Latin in high school. Anticipating what is now a fundamental precept of medical education, he was one of the few medical men of his day to submit himself to a prolonged training in the fundamental disciplines. He spent nine years in intensive studies in physiology, chemistry, biochemistry, pharmacology and medicine under such leaders of European science as Carl Ludwig, Schmiedeberg, von Nencki and Hoppe-Seyler. He received the M.D. degree in 1888 from the University of Strasburg and, while still an assistant in Schmiedeberg's Institute at Strassburg, he was called to his Alma Mater in 1891 as professor of materia medica and therapeutics (a title equivalent to that of professor of pharmacology). He remained at Michigan about two years and in 1893 accepted the chair of pharmacology at the Johns Hopkins, where he remained until his retirement in 1932.

His investigations, which covered a wide variety of subjects,[1] early brought him recognition both here and in Europe. He was dean of American pharmacology not only by virtue of his status as an investigator but because of his scholarly and kindly personality. He was the recipient of numerous medals and prizes. Universities both here and abroad awarded him honorary degrees. He held membership in many learned societies and was an honorary member of several foreign scientific societies and academies. Only a few days before his death he received news of his election as a foreign member in the Royal Society of London, an honor awarded only for the highest scientific achievements to persons outside the British Empire. Not least among his contributions to the advancement of the biological sciences was the founding of the *Journal of Biological Chemistry* with the late Dr. Christian A. Herter in 1905, and the *Journal of Pharmacology and Experimental Therapeutics* in 1908. He was also one of the founders of the American Society of Pharmacology and Experimental Therapeutics and was its first president. His sphere of influence was wide, and among his most devoted friends and admirers were not only his pupils but others whom he helped or advised either in their research work or personal matters.

In his scientific work Professor Abel was consciously a pioneer. Having opened a new path, he was content to leave its filling and paving to others. Attractive problems to him were those where knowledge was scant and where progress was made not by the application of accepted techniques, but by ingenuity and resourcefulness. His apparatus for vividialysis, colloquially known as the "artificial knidney," is a case in point. By means of this apparatus he was the first to demonstrate the existence of amino acids in the circulating blood. For the most part, his work was centered around the isolation, as chemical entities, of physiologically important substances both of plant and animal origin. The

[1] For a more detailed account of Professor Abel's investigations and early life see this Journal for 1932 (Vol. 34, p. 182).

PROFESSOR JOHN JACOB ABEL

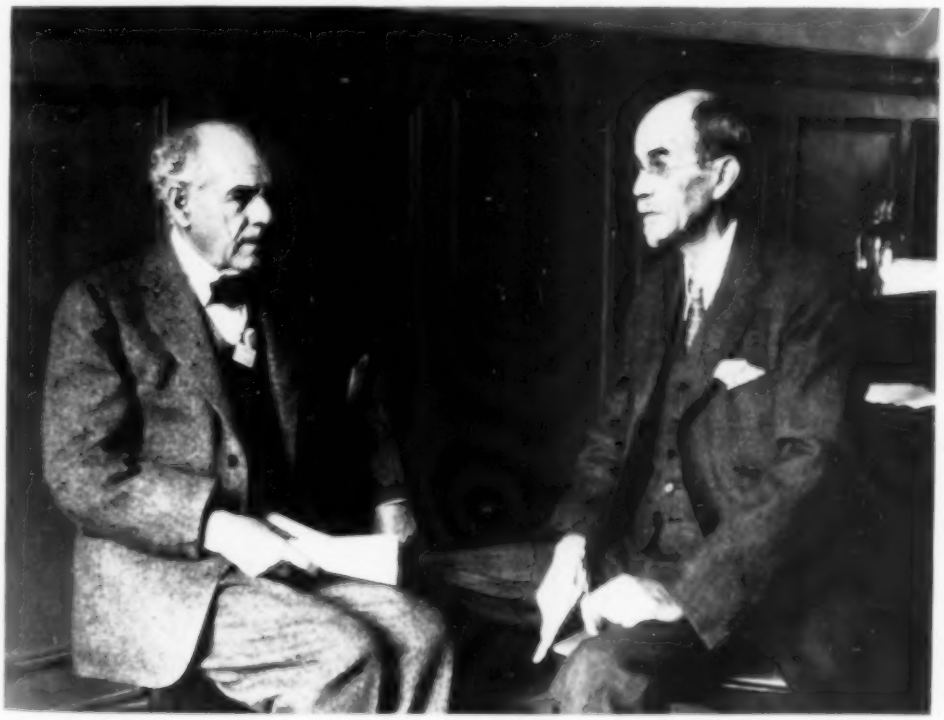
FROM A PORTRAIT PAINTED BY MR. GRIFFITH COALE IN 1918 AND PRESENTED TO THE JOHNS HOPKINS UNIVERSITY BY A GROUP OF DR. ABEL'S FRIENDS. THE PORTRAIT NOW HANGS IN THE WELCH MEMORIAL LIBRARY.

crystallization of the pancreatic hormone, insulin, and the isolation of epinephrine as a monobenzoyl derivative are perhaps the most important of his contributions to our knowledge of the chemical nature of tissue constituents. He frequently expressed his especial delight in the exact nature of the knowledge afforded by pure chemistry. And yet he was not afraid to enter those fields of biology where the dynamic nature of the processes, coupled with imperfect techniques, make the path of the scientific wayfarer tedious and treacherous. As late in life as his seventy-fifth year, he welcomed his retirement from active academic service as permitting his undivided attention to his investigations. It is characteristic that, at an age when the average investigator retires to a life of leisure or at most devotes his time to an extension of his earlier work, Professor Abel should desert his chemical interests and enter what was for him an essentially new field of investigation. A critical analysis of the data convinced him of the inadequacy of the current belief that the toxin of the tetanus bacillus reaches the central nervous system by traveling along the peripheral nerves. He embarked, therefore, on an extensive series of experiments which were still in progress at the time of his death. He brought to these researches the characteristic enthusiasm and tenacity of purpose which were so inspiring to his associates; and although

it is perhaps too early for a final estimate of these investigations they have already served to re-focus attention on what was regarded as established fact.

During the course of his long career Professor Abel collaborated freely with his assistants and many of his publications bear the name of one or more of his associates. He frequently expressed his enjoyment of such association and the personal charm and the unassuming democratic spirit that he evinced in the daily contact of laboratory life left a lasting impression on the succession of young men who passed through his laboratory. It was in this respect that he was most effective as a teacher. He had a long list of pupils, many of whom have attained distinction and hold professorships here and abroad.

He was, *par excellence*, the investigator. To him successful research was its own reward and he consistently declined opportunities to commercialize his findings. His adherence to such principles was a significant influence in elevating the status of pharmacological research in this country. He freely recognized his errors and had developed a wholesome philosophy toward them. Mistakes were regrettable and to be avoided, but too great a feeling of personal chagrin at their commission indicated to him an exaggerated conception of the contribution any one individual may make to the general fund of scientific knowledge. His attitude toward his work is perhaps best summarized in a statement from Lessing which deeply impressed him as a young man and which he frequently quoted:



PROFESSOR JOHN JACOB ABEL

IN CONVERSATION WITH A FRIEND AT THE BOSTON MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE IN 1932, WHEN HE GAVE THE ADDRESS OF THE RETIRING PRESIDENT.

Nicht die Wahrheit, in deren Besitz irgend ein Mensch ist, oder zu sein vermeinet, sondern die aufrightige Mühe, die er angewandt hat, hinter die Wahrheit zu kommen, macht den Werth des Menschen. Denn nicht durch den Besitz, sondern durch die Nachforschung der Wahrheit erweitern sich seine Kräfte, worinn allein seine immer wachsende Vollcommenheit bestehet. Der Besitz macht ruhig, träge, stolz.

Wenn Gott in seiner Rechten alle Wahrheit, und in seiner Linken den einzigen immer regen Trieb nach Wahrheit, obschon mit dem Zusatze, nicht immer und ewig zu irren, verschlossen hielte, und spräche zu mir: Wähle! Ich fiele ihm mit Demuth in seine linke, und sagte: Vater gieb! Die reine Wahrheit ist ja doch nur für dich allein!

However brief, no appreciation of Professor Abel would be complete without reference to the important role played in his life by the late Mary Hinman Abel, who died in January of this year. Throughout an association of some sixty years, she was companion and adviser, a devoted wife and mother. She was a woman of remarkable personal accomplishment and charm; the author of several books and numerous articles on diverse topics, editor of the *Journal of Home Economics* and active in the civic affairs of the community. The diversity of her interests, however, did not interfere with her participation in the life of her husband and in her unselfish desire to further the progress of his work in every manner. Jointly, their lives represented the finest fulfilment of the ideals of our civilization.

E. M. K. Geiling
E. A. Evans, Jr.
The University of Chicago

THE PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON

Dr. Vannevar Bush, vice-president and dean of engineering of the Massachusetts Institute of Technology, has been elected president of the Carnegie Institution, and will take office in January. He succeeds Dr. John C. Merriam, who has served as president of the institution for seventeen years.

Dr. Bush is a native of Everett, Mass., the son of the late Reverend R. Perry Bush, for fifty years a clergyman in the vicinity of Boston. He was graduated from Tufts College in 1913, and in 1916 was awarded the degree of doctor of engineering from Harvard University and the Massachusetts Institute of Technology. In 1932 he received the honorary degree of doctor of science from Tufts College, of which he is a trustee.

Dr. Bush joined the faculty of the institute in 1919, as professor of electric power transmission, and was appointed vice-president and dean of the School of Engineering in March, 1932. At the same time he was elected a member of the corporation. Early in his career, Dr. Bush held a position in the test department of the General Electric Company and then returned to Tufts College as an instructor in mathematics, subsequently becoming assistant professor of electrical engineering.

Dr. Bush has been interested in the design of advanced mathematical analyzing instruments and has had charge of a group of research workers who have produced several important instruments of this type. In recognition of this work he was awarded the Levy Medal of the Franklin Institute in 1928 and the Lamme Medal of the American Institute of Mining Engineers in 1926.

As president of the Carnegie Institution, Dr. Bush will hold an administrative position in one of the largest foundations devoted to the advancement of knowledge by research. Its resources include various research stations and its interests range from astronomy to archeology. Among the branches of the institution are the Mount Wilson Observatory, in California; the Desert Laboratory, at Tucson, Arizona; the Station for Experimental Evolution, at Cold Spring

DR. VANNEVAR BUSH

VICE-PRESIDENT AND DEAN OF ENGINEERING OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY, WHO HAS BEEN ELECTED PRESIDENT OF THE CARNEGIE INSTITUTION OF WASHINGTON.

Harbor, Long Island; the Biological Station in the Dry Tortugas Islands in the Gulf of Mexico; the Botanical Laboratory at Monterey, California; the Nutrition Laboratory in Boston and the Laboratory of Embryology in Baltimore. In Washington it maintains a large geophysical laboratory, a Department of Terrestrial Magnetism and a division for historical studies. The laboratories and administrative buildings in Washington are the headquarters for its scientific projects. In Mexico and Central America the institution has made extensive archeological studies of the great Mayan ruins. Its work is carried on under an endowment of approximately $34,000,000.

Commenting on the appointment of Dean Bush, Dr. Karl T. Compton, president of the institute, said:

> Dean Bush is so eminently qualified for his new position, and the post is of such great influence and opportunity in the field of science and human welfare, that his colleagues at Technology are unanimous in their approval of his selection. As they feel pride in his recognition and satisfaction in his enlarged new opportunities, they nevertheless will sadly miss his keen and ever constructive counsel and direction. To me, personally, Dean Bush has been so loyal as a friend and has shown such good judgment and analytical power in his administrative work as vice-president of the institute that it is only the magnitude of his opportunity that enables me to say that I am sincerely glad in the new situation, both for him and for the Carnegie Institution. His rare capacity for making an original constructive contribution to the solution of every problem that comes to him will be a great asset in directing the far-flung affairs of the Carnegie Institution.

SEISMIC WAVES

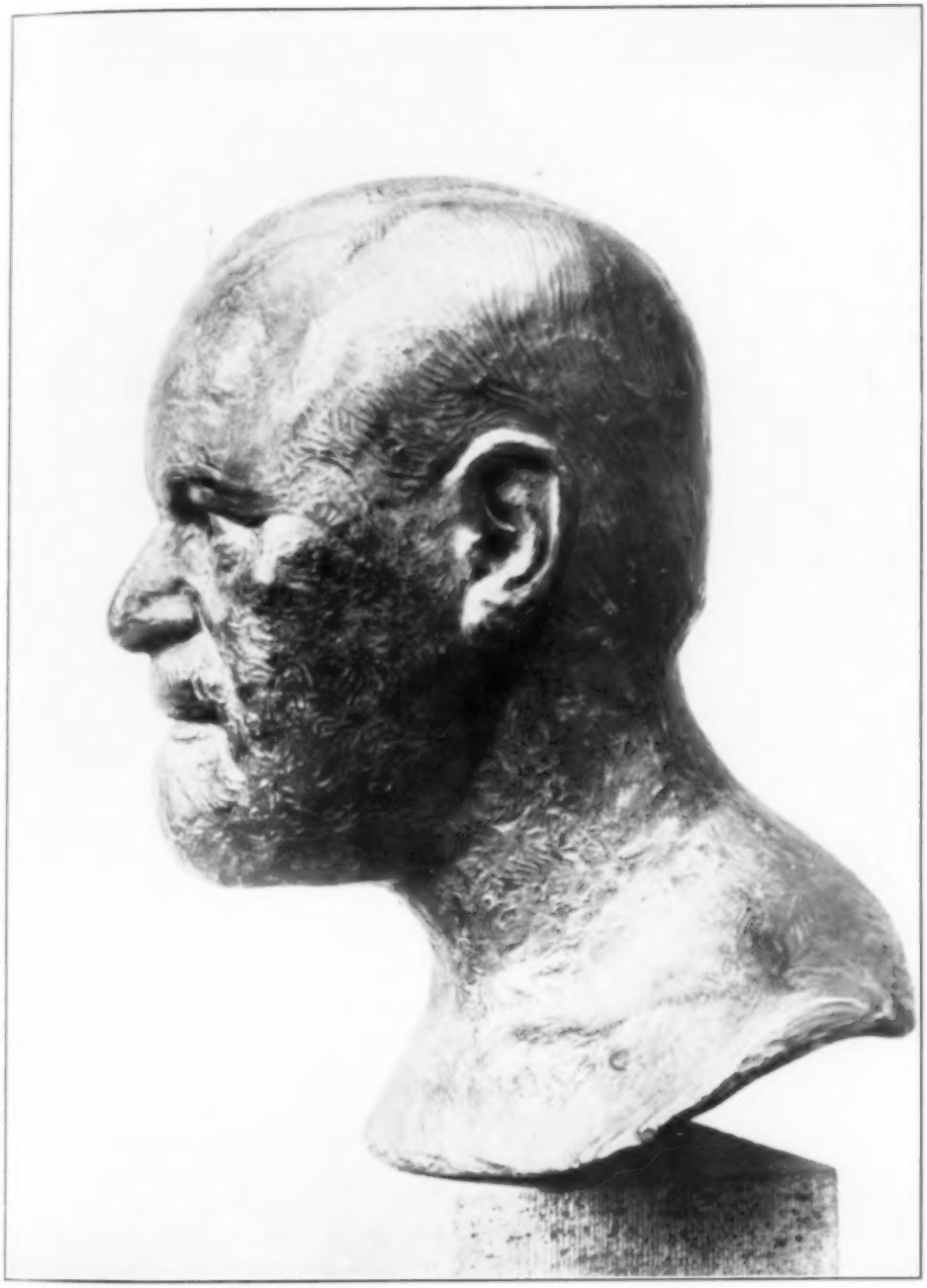
The Geological Society of America announces that artificial earthquakes, set off by powerful quarry blasts, will be studied by geologists this summer to determine the structure of the earth's crust to depths more than twenty miles below the surface. Observing staffs will be stationed at varying distances from several large quarries in New England with instruments more delicate and more sensitive than those usually employed in measuring real earthquakes.

Dr. Louis B. Slichter, professor of geophysics at the Massachusetts Institute of Technology, will direct the study under a grant of $5,350 from the Penrose bequest of the society. Dr. Slichter hopes that the recording of the blasts will shed light on the popular geological hypothesis that the earth's crust is composed of a number of layers of rock, not unlike the physical make-up of the onion.

Fresh knowledge concerning the structure of the earth's crust at depths of twenty miles and more, and new data on the nature and depth of the transition from the layer of granite to the underlying rocks, is one object of the investigation. At present the earth is conceived by some geologists to consist of a series of concentric shells; an outer layer of sedimentary rocks, an underlying granite-gneiss shell, a shell of periodotite or basic rock and a core of nickel and iron, with a transitional layer between the periodotite and the core. To bolster or deflate this theory is another objective.

Twelve super-sensitive portable seismographs, especially designed by Dr. Slichter for the project, will be placed at regular intervals within a hundred miles or more from the point of the blast to record the results of the man-made earthquakes. Supplemented by radio receiving apparatus and a central control board, each seismograph station will be equipped to record most microscopic tremors. More than twenty-four observers will man the field stations.

The gigantic blast will be recorded on instruments many miles away as a series of jagged lines. So delicate are the



DR. SIGMUND FREUD

FOUNDER OF PSYCHOANALYSIS, WHO HAS BEEN DRIVEN FROM VIENNA AT THE AGE OF EIGHTY-TWO YEARS AND IS NOW LIVING IN LONDON. THE BUST, BY PAUL KÖNIGSBERGER, WAS MADE ON DR. FREUD'S SEVENTY-FIFTH BIRTHDAY FOR THE GERMAN PSYCHOANALYTIC SOCIETY.

SUPERSENSITIVE SEISMOGRAPH TO RECORD MAN-MADE EARTHQUAKES

DR. LOUIS B. SLICHTER ADJUSTING ONE OF THE TWELVE NEW SUPERSENSITIVE SEISMOGRAPHS WHICH, IN A STUDY SPONSORED BY THE GEOLOGICAL SOCIETY OF AMERICA, WILL BE USED THIS SUMMER TO RECORD ARTIFICIAL EARTHQUAKES SET OFF BY QUARRY BLASTS IN NEW ENGLAND. EARTH MOVEMENTS AS SLIGHT AS A HUNDRED THOUSANDTH OF AN INCH CAN BE RECORDED WITH THE DEVICE, WHICH IS MORE DELICATE AND MORE SENSITIVE THAN THE ORDINARY SEISMOGRAPH WHICH RECORDS REAL EARTHQUAKES.

supersensitive seismographs that they are capable of detecting a ground movement as slight as a hundred-thousandth of an inch. The size of the blast will determine the distances at which the field stations will be located.

It is expected to obtain information on the nature of rocks at varying depths by measuring the time elapsing between the detonation and the recording of the shock at the field stations. Through a microphone and radio transmitting apparatus at the scene of the blast, all field stations are simultaneously apprised of the explosion, which is automatically recorded on a tape.

When the ground tremors finally reach the machine through different underground paths, they are registered on the same tape. The space on the tape between the record of the blast as received by radio and the record marked by the seismograph gives the time consumed by the tremors in reaching the field stations. These records will be analyzed and calculated by special machines at the Massachusetts Institute of Technology.

Seismic waves travel more swiftly in rocks of increasing depth. Dr. Slichter expects that his research will determine accurately how swift wave velocities travel in the deeper crustal rocks. The part played by depth in the variation of wave velocities will also be investigated.

While the actual field work will be completed this summer, the entire program, including interpretation of the results in the laboratories of the Massachusetts Institute of Technology, will occupy a year.